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FINAL REPORT
BUOYANT VENUS STATION
FEASIBILITY STUDY

Volume VI - Technical Analysis of a 2000- and 5000-lb BVS

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FOREWORD

This final report on the Buoyant Venus Station Feasibility Study is submitted by the Martin Marietta Corporation, Denver Division, in accordance with Contract NAS1-6607.

The report is submitted in six volumes as follows:

- Volume I - Summary and Problem Identification;
- Volume II - Mode Mobility Studies;
- Volume III - Instrumentation Study;
- Volume IV - Communication and Power;
- Volume V - Technical Analysis of a 200-lb BVS;
- Volume VI - Technical Analysis of a 2000- and 5000-lb BVS.

CONTENTS

FIGURES

FINAL REPORT

BUOYANT VENUS STATION FEASIBILITY STUDY

VOLUME VI - TECHNICAL ANALYSIS OF A 2000- AND 5000-LB BVS

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MISSION MODE TRADEOFF STUDIES - TASK 4.5

For each mission mode investigated, the contractor shall select, subject to government approval, the most promising mobility method or methods and perform mission mode tradeoff studies in the prescribed ranges of the Venusian atmosphere.

As part of the midterm Oral Briefing, the recommendation was made and accepted that during the remaining period of the study (Mission Mode Tradeoff) part of the effort would be concentrated on a nominal 2000-lb station.

SUMMARY

The volume presents the results of the analysis of the feasibility of the 2000-lb buoyant Venus station (BVS). It is intended that this vehicle would complement a Voyager-class mission to Venus.

This station is the direct outcome of the original constraints of the Buoyant Venus Station Feasibility Study, which specified a weight limit at deployment of 5000 lb. This is the most attractive use of the balloon concept. The large payload and the mobility and long life make the station particularly suitable as a platform for the experiments of the relatively sophisticated and complicated scientific missions of the Voyager missions. Even if a true (survivable) lander were to prove feasible, it would not present the equivalent advantages of this station as a platform for experiments.

As this study makes clear, the 2000-lb weight is neither optimum nor restrictive. In an earlier phase of this study, 175 lb of scientific instrumentation (excluding drop sondes) were identified. This, in one form or another, related to practically all of the high-priority information desired about Venus. While this list in no manner exhausts the possibilities for experiments or instruments, it suggests that a complement of three or four somewhat smaller stations, say 1000 to 1500 lb, for each Voyager bus would be reasonable. Similarly it is equally reasonable to project a 5000-lb or larger station for as yet undefinable future missions. An envelope and weight statements for both cyclic and noncyclic modes of the 5000-lb station are included in this volume. Figure 1 shows two of the 2000 pound stations within a Voyager (Mars) aeroshell and envelope by way of illustration. Several smaller aeroshells (for separate entry and deployment) would also be appropriate for consideration.

The major development areas are again (as with the 200-lb station) associated with the balloon and its controls. More leeway exists, however, in the solution of these problems in this case because of the reduced criticality of weight.

INTRODUCTION

The starting points for this design concept were generated in the preliminary tasks of this study. The most sophisticated scientific mission suggested by the instrumentation lists called for 137 lb of instrumentation supported by drop sondes. For this design, an additional 58 lb of instrumentation was added, which with 105 lb of sondes brought the scientific payload to 300 lb.

The most obvious mission, from the wind pattern analysis of the instrumentation study, could take as long as 100 days as the balloon drifted (approximately) from near the subsolar point over the pole to the vicinity of the antisolar point. This long a mission, of course, aggravates the problem of communication with the orbiter, increasing the problem of drifting out of line of site. (Several stations, deployed separately, would be particularly attractive in this regard.)

The scientific mission is described in detail later in this volume. A degree of complexity was deliberately introduced into the mission to assure that the conclusion of feasibility would not be limited to relatively simple missions, such as might be associated with (only) the early missions.

Figure 2 indicates the deployment sequence. A separate mode of data collection including engineering instrumentation is provided for this critical phase to assure that fundamental information is not lost.

A concept of packaging the BVS in an aeroshell is indicated in figure 3. The hexagonal gondola is 6 ft across and approximately 2 ft deep. The internal arrangement does not appear to be critical. An RTG (40 W) is shown as the source of both electric power and heat for thermal control.

Figure 4 shows an arrangement of the cyclic version with three external hydrazine tanks. This cyclic system weighing 236 lb would permit the entire vehicle to descend to 10 km and rise three times, dropping one tank each time.

The overall weight breakdowns for the noncyclic and cyclic stations are given in tables 1 and 2, respectively. It is apparent that the noncyclic station could be reduced in size. However, it should be recognized that for this relatively complex mission, a degree of redundancy or other reliability enhancing techniques should be employed, which have not been considered in this study.

SYMBOLS

A/D	analog to digital
AGC	automatic gain control
APC	automatic phase control
BPF	bandpass filter
BPS	bits per second
B_{rf}	radio frequency bandwith (predetection)
B_v	video bandwith
BVS	buoyant Venus station
BW	bandwidth, cps
CP&S	central programer and sequencer
DAS	data automation system
f_c	center frequency of filter

f_d	NRZ data
f_o	sync subcarrier frequency
f_s	bit sync frequency
g	acceleration of gravity, ft/sec^2
IR	infrared
KBPS	kilobits per second
mil	one-thousandth of an inch
NRZ	nonreturn to zero
PBI	Polybenzimidazole (polymer)
P_e^b	bit error probability
RTG	radioisotope thermoelectric generator
SNR	signal-to-noise ratio
SNR_i	input signal-to-noise ratio
SNR_o	output signal-to-noise ratio
ST/(N-B)	signal energy per bit
VCO	voltage-controlled oscillator
ZOI	zero order interpolator
α	absorptivity, dimensionless
β_o	modulation index, radians (data channel)
β_s	modulation index, radians (sync channel)
ϵ	emissivity, dimensionless
θ	true anomaly (refers to orbit)
σn^2	limiter noise suppression factor
σs^2	limiter signal suppression factor
φ	drift angle of station on great circle path from initial position toward planet's south pole

SCIENCE SUBSYSTEM

The selection of experiments for the 2000-lb BVS was based partially on the assumption that the mission was an early one. However, the fact that a 2000-lb BVS is a Voyager-class mission implies that it will not be the first probe to enter the atmosphere of Venus, and that more will be known about the atmosphere of Venus than we have assumed.

This increased knowledge will change the selected payload little, if any, as far as the number and type of experiments is concerned. It will, however, have a marked effect on the conduct and detailed design of the experiments. Thus, the experiments will be more refined and broad coverage will not be as important as higher resolution. Indeed, the earlier missions may answer the question of how much emphasis should be placed on biological experiments.

Experiments

The experiment complement for the 2000-lb BVS is shown in table 3. The ion chamber and some of the uv, visible, IR radiation flux experiments are contained in a package at the apex of the balloon; all others are contained in the gondola. The total weight of experiments on the BVS is 137 lb; allowing 105 lb for drop sondes and 58 lb for undefined experiments or ancillary equipment brings the total weight of the science subsystem to about 300 lb. A brief discussion of each experiment is given below.

Atmospheric temperature. - Platinum resistance temperature sensors are mounted on booms extending from bays 3 and 5. There are two sensors per boom covering the ranges 200 to 500°K and 500 to 800°K. Extending the booms 2 or 3 ft from the gondola should allow the ambient temperature to be measured within ±5°K. Better accuracy could be obtained by lowering the sensors on a cable several balloon diameters long.

Atmospheric pressure. - Ten pressure sensors cover the pressure ranges 0 to 1, 1 to 10, 10 to 100, 100 to 1000, and 1000 to 10 000 mb with two sensors per range for redundancy. The sensors are mounted in bays 2 thru 6 (refer to fig. 3).

Acoustic transmission line. - This experiment, by measuring the speed of sound, acoustic impedance, temperature, and pressure of a sample of the atmospheric gas, determines the density and mean molecular weight of the atmosphere. Entrance and exit ports are required to collect and exchange atmospheric samples.

Mass spectrometer. - This instrument has a quadrupole analyzer section that can separate ions in the range 10 to 50 amu. This range includes the following gases and dissociation products:

amu	Gas or component	amu	Gas or component
12	C	30	C_2H_6 and HCHO
14	N	32	O_2
16	O and CH_4	34	$C\ell$
17	NH_3	35	$HC\ell$
18	H_2O and F	40	A
19	HF	44	CO_2 and N_2O
20	Ne	46	NO_2
28	N_2, CO, and C_2H_4		

The mass spectrometer requires a gas sampling and exchange system. Since leakage gases from the balloon may contaminate the ambient gas, a long tube or hose may be required to get uncontaminated samples.

Pyrolysis/gas chromatograph/mass spectrometer. - This combination of instruments will be used to determine the composition of clouds and dust particles and the presence of organic compounds in the atmosphere. A cyclone separator will be used to collect the particulates for analysis. The particulates are pyrolyzed in a controlled manner and presented to the gas chromatograph; the mass spectrometer is used to analyze selected components that pass through the gas chromatograph unresolved.

Vidicon microscope. - This experiment takes television pictures of encapsulated dust particles (or biota) collected by another cyclone separator. A total of 18 pictures per sample are taken;

three fields of view, six focus levels per field of view. After a sufficient dust collection time, a command from Earth initiates encapsulation of a dust sample and one picture is sent to Earth. If this picture shows sufficient dust or biota, the remaining pictures are taken and the remaining dust sample presented to the biological laboratory for analysis, otherwise, dust collection continues.

Minimum biological laboratory. - This instrument is a combination of several simple life-detection experiments incorporating, for example, metabolism of radioactive substrates and evolution of labeled gases, detection of photosynthesis, assay for microbial ATP, and metabolic uptake of phosphorus and sulfur; several other experiments are also possible. Dust samples, collected by the same cyclone separator used for the vidicon microscope, are deposited in a hopper on the instrument and distributed to the various experiments for analysis. Analysis requires about 100 hr and readings are taken once every orbit.

Ion chamber and Geiger tube. - This instrument is a low priority experiment included mainly to be representative of instruments affected by RTG radiation. By placing it at the apex of the balloon, the background count due to the RTG becomes tolerable without shielding. The instrument is the same as that flown on Mariner IV.

Ultraviolet radiation flux. - This experiment would measure the continuous absorption of near-uv radiation in several wavelength regions ($4000\ Å \gtrsim \lambda \gtrsim 2000\ Å$). This would indicate the nature of the clouds or haze above the BVS and the presence of ozone. The experiment is mounted at the apex of the balloon to ensure viewing the sun.

Visible/near-IR radiation flux. - The atmospheric transmission at 25 wavelengths between about 4000 Å and 6 μ is measured with this experiment, which is located at the apex of the balloon. The filters are chosen to pass wavelengths absorbed by atmospheric gases (e.g., H_2O, CO_2). A similar experiment mounted on the gondola looking down would be a desirable adjunct.

Altimeter/radar scatterometer. - This instrument provides both altitude and information on the scattering and electrical properties of the surface. The device is a pulse radar with a stepped scan, phased-array antenna that scans a 60° field of view. Development work on such an altimeter has been done at Texas Instruments for Langley Research Center.

Microwave scanner/spectrometer. - This instrument is a passive, multifrequency, microwave radiometer. One-dimensional electronic scans at 4 wavelengths between 3 cm and 3 mm yield information on the atmospheric composition, thermal structure, circulation, and density. A two-dimensional electronic scan at a wavelength between 3 and 4 cm gives a thermal map of the surface.

Infrared scanner/spectrometer. - This experiment is essentially the IR counterpart of the microwave scanner. One-dimensional scans at several wavelengths between about 4 and 12 μ give information on the clouds and atmopshere while a two-dimensional scan at 3 to 4 μ would give a thermal map of the surface when the BVS descends below the clouds or a thermal map of breaks in the clouds.

Light backscatter from aerosols. - This experiment consists of 10 detectors viewing the light from a pulsed or chopped source that is backscattered at different angles from cloud or aerosol particles. The scattering angles lie between 180 and 135°. Two detectors at each angle measure the backscattered light at two wavelengths. The intensity of the backscattered light is proportional to the concentration and scattering cross section of the particles.

Drop sondes. - The drop sonde complement for the 2000-lb BVS consists of four 25-lb sondes and one 5-lb sonde. The large drop sondes would carry experiments selected from those in table 4. The small sonde carries only pressure and temperature sensors.

Scientific Data Acquisition

For convenience, the measurements are arranged into four basic groups and several special groups as discussed below.

Group I measurement. - These measurements, shown in table 5, are made 6 times every orbit at 0, 0.75, 1.5, 2.25, 3.0, and 3.5 hr of each orbit with the exception of the first orbit.

First orbit measurements. - After the BVS is deployed and floating at equilibrium altitude, the Group I measurements are started and taken every 0.75 hr until the orbiter comes into view for the first time. In addition, the mass spectrometer makes one atmospheric composition analysis and the small sonde measuring temperature and pressure is released. The data gathered during the first orbit are transmitted to Earth via the orbiter for a quick analysis.

Group II measurements. - Table 6 shows the experiments included in this group. On command from Earth, the dust collected during the preceding orbits is distributed to the instruments. One dust collector presents its sample to the pyrolysis/gas chromatograph/ mass spectrometer experiment for analysis. The other dust collector presents half of its sample to the vidicon microscope and half to the biological laboratory. The vidicon microscope encapsulates its sample and takes one picture. The biological laboratory sample remains in its hopper until a command from Earth is received to start the analysis. The first vidicon picture is then transmitted to Earth via the orbiter for analysis. If enough dust is present, a command is sent to take the remaining 17 pictures and to start the biological laboratory analysis, otherwise the dust collectors continue to collect more dust. These measurements are denoted as Groups IIA and IIB in table 6.

Group III measurements. - This group of "imaging" experiments functions every third orbit except when a drop sonde is released. Table 7 lists the experiments in this group.

Drop Sonde measurement. - Drop sondes are released on command from Earth in place of Group III measurements. Total data from any sonde will be less than 100 000 bits.

Group IV measurement. - This group of measurements is made during cycling or final descent. The Group I experiments and the light backscatter experiment are activated by a pressure switch approximately every 5 km or by a timer every 0.75 hr. The mass spectrometer and the IR scanner/spectrometer make measurements every 10 km. The IR scanner functions as a four-channel, down-looking radiometer during descent and a two-dimensional scan is made at the minimum cycle altitude. Group I measurements only are made during ascent. Table 8 lists the measurements in Group IV.

Typical Sequence of Events

After the BVS is deployed and has attained its equilibrium altitude, the experiments and sensors are deployed and checked out, the Group I measurements are started, the mass spectrometer makes one analysis, the dust collectors are started, and the small drop sonde is released.

When the orbiter makes its first appearance, the data are transmitted to Earth via the orbiter for analysis. Group II only measurements are made during the next several orbits, while the first orbit data are being analyzed.

At the beginning of the third orbit, Groups II and III measurements are commanded to start. Group III measurements are made every third orbit hereafter unless a drop sonde release command is given.

At the beginning of the sixth orbit (after the first vidicon picture has been analyzed on Earth), Groups IIA and IIB measurements are commanded if enough dust has been collected. The biological laboratory measurements are made once per orbit for 35 consecutive orbits. Group II measurements are commanded again followed by Groups IIA and IIB if enough dust is present. The above measurements continue until a cycle command is given. Then, all measurements stop (except Group IIB), and Group IV measurements are made. The other measurements resume when the station ascends to its original equilibrium altitude.

When the terminator is crossed, a large drop sonde is released. When the mission is complete, for example, when the BVS is about to pass out of communications range, the station is given the command to descend and Group IV measurements are made until impact.

Problem Areas

Except for the specialized requirements of the individual experiments, the science subsystem for the 2000-lb BVS presents no problems that were not uncovered with the 200-lb BVS. The uncertainty in the wind pattern remains the only fundamental problem.

BALLOON SUBSYSTEM

The uncertainty of the Venusian atmosphere, and, hence, the large spread in the three model atmospheres, penalizes the design of the balloon subsystem. Sufficient gas has to be transported for the worst-case atmosphere (upper density) only to be valved off in the mean and lower models. The models also make it undesirable to guarantee floatation above the clouds in all three models. It is presumed that this large, complex station will be preceded by earlier probes into the atmosphere narrowing this atmospheric uncertainty considerably.

Both the noncyclic and cyclic stations are discussed in this section. The cyclic station may use any of three methods: (1) gas dump and makeup; (2) gas dump and ballast drop; and (3) pump and dump of atmospheric gases.

Analyses were performed in evaluating inflation gases (hydrogen and decomposed hydrazine), cyclic methods and cycle gas systems, and balloon materials.

Balloon

Noncyclic station. - The balloon is designed for a minimum mission duration of 100 days floating at 57 km in the mean density atmosphere with a superpressure of 6 mb. In this atmosphere, the station is approximately 1.8 km above the clouds. In the lower density model, the station floats at approximately 40 km, which may be within the clouds. In the upper density atmosphere, the station will float at approximately 79 km, which is well above the clouds. The ambient temperature lies between 195 and 287°K in the upper and lower density atmospheres, respectively.

The balloon is fabricated from Mylar. This is based on good physical properties within the expected temperature range and on the current state of technology with respect to balloon fabrication and design. The basic construction is a lamination of two films of 1.25 mil each. The resulting balloon design is shown in figure 5.

Pertinent data are as follows:

1) Volume, 94 400 cu ft;

2) Diameter, 56.6 ft;

3) Surface area, 10 050 sq ft.

Balloon design details are shown in figures 6 and 7. Nylon-reinforced Mylar is used for the cap plate and the inflation fitting mating area to produce a gradual transition to high stress points. The top cap assembly allows for storage of approximately 15 lb of instruments, controls, and associated thermal control material. The controls may include a redundant pressure switch and relief valve for control of superpressure. A diffuser plate and sock are used to reduce the velocity of the inflation gas and eliminate the possibility of direct impingement of a high-velocity gas stream on the balloon skin.

The basic balloon shell fabrication shown consists of attaching identical gores together with Mylar adhesive-backed tape. The laminated Mylar has improved properties over single film with regard to gas permeation and handling characteristics. The load suspension consist of a nylon cone attached to the balloon skin forming a tangent harness. The included angle is approximately 120°.

The calculated skin stress resulting from the 6-mb superpressure is approximately 6000 psi. The suspended load imposes a load of approximately 0.5 lb/in. The stress of 6000 psi corresponds to a skin load of 15 lb/in. This substantial differential ensures a minimum deformation from the spherical shape.

Cyclic station. - The balloon is designed for a minimum mission duration of 100 days floating approximately 57 km in the mean density atmosphere with a superpressure of 6 mb. In addition to this, the balloon must withstand a minimum of three cycles to a minimum altitude of 10 km with no dwell time. The maximum ambient temperature expected is 675°K (in the upper density atmosphere).

The balloon is fabricated of polybenzimidazole (PBI) film, which has an operating temperature range of 4 to 723°K. However, since there is no existing technology with respect to balloon design and fabrication, the resulting design is strictly conceptual. Kapton film may be considered for this application but has no technology basis for this application either. Two PBI films are laminated, each film 1.25 mil thick. The resulting balloon design is shown in figure 8. The size is identical to that of the noncyclic station.

Balloon design details are shown in figures 7 and 9. PBI fiber-reinforced PBI film (or Kapton) is used for the cap plate. The diffuser sock has to withstand the high-temperature gases of decomposed hydrazine used as the cycle gas. The top cap assembly allows for storage of approximately 15 lb of instruments, controls, and associated thermal control material. The valving for cycling is located in this area.

The basic balloon shell fabrication shown consists of adhering identical gores together, overlapping each gore at its centerline as shown in figure 9. This will produce a continuous, constant cross-section membrane. The adhesive at this time is an unknown regarding adhesive efficiency. The gondola suspension consists of PBI fibers woven into a cone attached to the balloon skin forming a tangent harness. The skin stresses are identical to those of the noncyclic balloon that produces a safety factory of 3.67 based on PBI yield point of 22 000 psi (which is approximately the same as ultimate for this material).

Inflation Subsystem

Schematics of the balloon inflation and control subsystems are shown in figures 10 and 11. The hydrogen gas is stored at a nominal pressure of 4500 psia and is loaded through a manual fill valve. Pressure and temperature of the stored gas are monitored with transducers. The ordnance shutoff valve is opened on signal from a pressure switch sensing static pressure. The filter protects the balloon and downstream components from metallic particles generated from an ordnance valve firing. The orifice restricts the flow to ensure that the balloon is not subjected to an initial damaging flow rate. The guillotine is the separation device that allows the tank and upstream components to be disconnected from the station. The balloon shutoff valve is a normally open ordnance valve that is closed on signal from the flowmeter. The flowmeter signal is sent when the gas flow has reached a selected minimum value. Two other methods are considered for controlling the shutoff valve. A pressure switch that opens at a tank pressure in the range of 300 to 500 mb could be used; another method of control is using a selected time interval. The pressure switch sensing balloon superpressure controls the solenoid valve for the relief function. An alternative method would be use of a relief valve.

The hydrogen gas pressurant tank weight is based on a nickel-lined, filament-wound vessel. The filament may be glass or boron, which results in a weight of 11 lb of tank per pound of hydrogen gas. This weight is predicated on heat sterilization being accomplished in the unpressurized condition. The hydrogen would be loaded after being sterilized in a separate container.

The hardware required for balloon inflation along with quantity of each component required, unit weights, volumes, and power requirements are listed in table 9. The values shown are typical for similar components found on spacecraft to date. The development status and flight use of the components are shown in table 10. Mariner and Surveyor have used similar hardware. The primary difference between these flight-proven components and those required for this mission is sterilization. Ordnance squibs and valves have been subjected to sterilization temperatures at Jet Propulsion Laboratory and have functioned properly.

The pressure switch that controls the balloon superpressure appears to be within state of the art for the 1970 time period. The Air Force Cambridge Research Laboratory has flown a pressure switch with a setting of 10 mb and a bandwidth of 10%. A supplier of pressure switches, Servonic Instruments, has a pressure switch in engineering with a setting of 7 mb for production in 1968.

The relief valve presents a greater extension of the present state of the art. The requirements are shown in table 11. The small differential pressures for cracking, full flow, and reseat present problems of minimizing seat leakage. A pressure switch operating a solenoid valve is an alternative approach that eliminates the requirement for this valve.

Cycle Subsystem

The method used for cycling is gas dump and gas makeup. The makeup gas is decomposed hydrazine and is shown in figure 12 in schematic form along with the sequence of events for gas addition. Three cycles are shown with this station allowing for a gondola weight of 547 lb. The cycle subsystem weighs 236 lb for the three cycles as shown in the station weight statement of table 12.

On command the balloon vent (relief valve) valve is opened allowing the superpressure to be dumped. This produces a small mass change and allows the balloon to ascend a small distance (on the order of a few hundred feet). This allows for further venting of gas. Since the valve would be located within the top cap assembly, there exists a small differential pressure between the hydrogen gas and atmosphere, which produces a positive force to continue venting. As the venting continues the balloon becomes slack and starts descent. A timer control could be used for the control valve, in conjunction with monitoring altimeter or barometric changes to determine descent velocity. When proper velocity has been reached, no further venting is done. Based on computer data, if 20% of the hydrogen gas is dumped, the cycle time is approximately 4.5 hr to descend to 10 km and return to altitude in the mean atmosphere.

The hydrazine system uses a simple blowdown operation in conjunction with a timer. The tank and equipment upstream of the guillotine are jettisoned on completion of the filling operation as shown in figure 13.

The hardware required for cycle inflation along with quantity of each component required, component weights, volumes, and power requirements are listed in table 13. The development status and flight use of similar components are shown in table 14. This spontaneous catalyst has not been flown to date, but will be used on Titan III and flown in 1968.

Consideration must be given to the environment of the hydrazine. It is stable above 600°K, but will probably have to be protected at 675°K. However, since there is no dwell time at the high temperature, little insulation is required due to the thermal lag of the system.

Vernier Gas Subsystem

For a mission duration of this order (100 days), it may be highly desirable to include a gas supply to compensate for crossing the terminator and for component and joint leakage. Permeation is not a problem with Mylar or Kapton, but PBI permeation is not well known.

An effect of the station crossing the terminator from the sunlight side to the dark side is the change in balloon gas temperature and the resulting decrease in pressure. The case of the station floating approximately 2 km above the clouds in the mean density atmosphere has been analyzed for a range of balloon coatings considering incident and reflected radiation. Mylar, uncoated, is approximately 98% transparent to solar radiation, which may eliminate the problem of crossing the terminator with only 6-mb superpressure.

An aluminized finish will maintain a temperature change of approximately 25°K or 11% of the total temperature. To maintain a superpressure condition above the 105 mb ambient pressure, the superpressure required would be approximately 12 mb. This would result in an increased balloon weight of 185 lb plus 45 lb of additional hydrogen gas system. The vernier gas system (hydrogen gas) could maintain the 6-mb superpressure of this station with a 45-lb total weight.

If the station passes from the dark to the light side (or out of the clouds from within the clouds) only venting of gas is required.

A few pounds of hydrogen or hydrazine would ensure that small leaks in the balloon system would not terminate the mission prematurely. The gas could be controlled by the pressure switch monitoring balloon superpressure or by command through telemetry data analysis.

Deployment

The station deployment sequence is shown in figure 14. The equipment used to initiate the deployment functions is shown in figure 15. Parachute deployment is initiated at a given dynamic pressure, whereas the balloon deployment is initiated at an ambient pressure level. The parachute is deployed subsonically and designed to reach terminal velocity before the balloon is deployed. This ensures a minimum dynamic pressure on the balloon during deployment.

If the balloon is inflated above equilibrium altitude, gas must be relieved to ensure that design superpressure limits are not exceeded. This gas must be made up after obtaining near-equilibrium altitude to produce proper superpressure and is a weight penalty to the station. Inflation below equilibrium altitude requires that a minimum of 10% "free lift" is required to produce a reasonable altitude undershoot. This is a slight gas weight penalty since 6 mb corresponds to only 6% "free lift." A pressure switch set at a nominal pressure of 99 mb and with an ac-accuracy of ±2%, will allow the balloon to be inflated very close to equilibrium altitude and will not require a gas weight penalty. It will also ensure minimum undershoot of the station, which is highly desirable for the 57 km, equilibrium altitude station, just under 2 km above the cloud tops. The sequence of deployment is shown in figure 2.

Engineering Measurements

The engineering measurements that should be made during station deployment and for monitoring balloon parameters, during equilibrium floatation and throughout altitude cycling, are shown in table 15.

Trade Studies

Analyses were performed on inflation gases, cycle methods and cycle gases, and balloon materials, as shown in table 16.

Hydrogen gas, transported as a cryogen and as a high-pressure gas, was compared to decomposed hydrazine. The results of this comparison are shown in figure 16 for a station weight ranging from 2000 to 2500 lb. The cryogenic hydrogen system allows for a 6% greater gondola weight than hydrogen transported as a high-pressure gas, and a 23% greater gondola weight than decomposed hydrazine. However, the 6% gain is more than offset by the complexity of the vaporization equipment required to produce inflation gas. One method is by use of a hot-gas heat exchanger, using decomposed hydrazine (fig. 17). Other schemes that may be considered are:

1) Oxygen-hydrogen burning to produce hot gas for heat exchanger;

2) Fluorine-hydrogen burning (hypergolic) to produce the hot gas.

Neither of these have been investigated. The resulting balloon sizes for hydrogen gas are shown in figure 18.

The high-pressure hydrogen gas station weight breakdown is shown in table 17. A decomposed hydrazine gas station is shown in table 18.

Hydrogen attack on materials is a consideration. Titanium alloys will be attacked at ambient temperatures by hydrogen gas at 4500 psia and at lower pressures. The degradation takes the form of surface spalling until the tank is completely destroyed. In other words, no passivation effect takes place.

At cryogenic temperatures, the effect has not been noticed; however, design must consider the possibility that portions of the system may rise to temperatures at which the degradation will take place. Battelle Institute, which has done most of the work, has not produced specific data describing the transition point, but states that the condition can be critical.

Of the two titanium alloys that may be considered, 6Aℓ-4V ELI and 5Aℓ-2.5 SnELI, the latter is recommended. (ELI is the abbreviation for extra low interstitial.)

Nickel is not known to be attacked by hydrogen gas at either of the temperature conditions; therefore, a nickel-lined filament wound tank would be satisfactory. The fiberglas laminate is compatible with hydrogen.

Gas dump and ballast drop and pumping and dumping of atmospheric gases were considered in addition to gas dump and makeup. The resulting gondola weights for these modes of cycling are shown in figure 19 for a station weight range of 2000 to 2500 lb. Gas dump and makeup, using hydrazine, allows for the maximum payload followed by gas dump and ballast drop, gas dump and makeup, using hydrogen as the cycle gas, and pump and dump atmospheric gases, respectively. However, the pumping and dumping allows for an unlimited number of cycles while the other methods only allowed three cycles. In addition, pumping and dumping allows the station to move to a lower equilibrium altitude.

The three ballast drops of 112, 100, and 86 lb could produce a large complement of experiments to analyze belowstation atmospheric conditions.

A pump receiver (ballonet) approximately 16 ft in diameter is required to cycle the 2000-lb class station. This concept is shown in figure 20. The ballonet would be constructed of a metal mesh, such as 304 stainless steel wire 1 mil in diameter, supporting a gas barrier such as PBI film. The pump for this analysis is assumed to be a single-stage, centrifugal type developing a 4.5 pressure ratio, driven by an electric motor powered by an RTG supply. The pump requires more than 2 hr to add sufficient ballast (approximately 60 lb) to create a descent velocity sufficient to maintain momentum and thus cycle to a low altitude.

For the gas dump method of cycling, internal compartments, constructed of PBI film, each compartment sized for the amount of gas to be dumped, could be used. Each "internal" balloon would be vented on command for the descent portion of each cycle. This would ensure that the proper amount of gas was dumped and eliminate the loss of gas in excess of that derived through valving since the exhausted compartment would act as the gas seal. This arrangement creates complexity in the initial inflation sequence since the compartments would have to be inflated before the main balloon and isolated after being inflated.

Three balloon materials were considered for this mission as shown in table 19. Mylar is not compatible with the high temperatures encountered while cycling to low altitudes.

There is not sufficient technology for either PBI or Kapton to produce more than just a conceptual idea of a balloon using them as the film. However, a very conservative approach to stress levels, 600 psi, was used for the balloon designs and resulting weights. It appears that a weight difference of approximately 15 to 20 lb exists between these two films. This is not sufficient to select either as optimum. PBI does have the higher operating temperature limit and, therefore, would appear to be advantageous to use in the unknown Venusian atmosphere at low altitudes.

TELECOMMUNICATIONS SUBSYSTEM

A simple block diagram of the baseline telecommunications subsystem is shown in figure 21. This subsystem features an integrated coherent command, ranging, and telemetry approach for the BVS/orbiter links. Dual subcarriers for telemetry and command, and a pseudonoise turnaround ranging code are used. For the drop sonde to station link noncoherent frequency shift key modulation is used.

Use of data compression on picture and "scanning-instrument" data plus care in programing the acquisition and transmission of data has resulted in eliminating the need for a tape recorder; only core memories are used.

Following is a more detailed description of the various telecommunications subsystems and a detailed sequence of events for both a cyclic and noncyclic station beginning with separation of the station from the aeroshell. The sequences are carried through several orbits and conclude with final station descent.

Various design analyses, problem areas and tradeoffs are discussed in the analysis and tradeoff section which follows the subsystem description.

Data Management

Operating modes and sequences. - The station operates in several modes that are for the most part command modifications to a fixed program. Initial turn on of the system occurs at separation from the aeroshell. Deployment and engineering data are then transmitted by the telemetry transmitter for a fixed period of 20 min.

The station then releases a small drop sonde and enters the science data mode in which science data are sampled and stored at fixed intervals in core storage until the orbiter again comes into communication range.

Once communications have been established, the orbiter commands a ranging operation. Following ranging, the orbiter commands a data readout sequence to occur. Should no readout command be received within a given period by the station after establishing communications, a programed readout will occur. After a fixed period of data transmission, the ranging mode is again energized, thus providing two ranging samples per orbit to be used in determining station position.

The orbital sequence of storing and transmitting science data is modified at intervals by the release of a drop sonde that transmits data to the station at a rate of 25 BPS while falling to the surface. The sonde data stored on the station replace Group III science data and are read out once per orbit until three readouts have taken place.

A typical sequence of events is shown in table 20, which involves a complete exercise of all science experiments. In addition, table 21 shows the additional sequence of events for a cyclic station. The final operation in the science mode is final descent, which is triggered on command from the orbiter. Descent takes place over approximately three orbital periods and is controlled by release of gas from the balloon. During this period, specified instruments are sampled at higher rates determined by pressure or temperature increments.

Data management subsystem. - The data management system is shown in block diagram form in figure 22; it is made up of a programer/sequencer, which controls all operational functions; a group of digital conversion units, which convert the analog instrument data to digital outputs; and a series of core memory systems to retain the data until a readout is commanded.

The programer/sequencer consists of a master timing oscillator and divider, a spacecraft time generator, a feedback shift register sequencer (which may be modified by command inputs), a sync generator, and a program control register. These elements with their associated control logic control all station sequence and program functions. For any time increment, a specific instrument is turned on, it inputs data to an analog-to-digital converter, and the digital output is placed into a core memory. Upon receipt of a readout command, the programer/sequencer causes the data selector to connect the core memories to the data output bus in a preestablished sequence and precedes the data with the required sync information.

Digital conversion is accomplished by successive approximation devices of two types. The first is an analog-to-digital (A/D) converter, whose input is provided by an analog multiplexer, the second is a variation of the first referred to as a multiverter in that the analog multiplexer is inherent in the converter and is design limited to less than six analog input channels.

The core memory systems are all of the serial-sequential type that produces lower power and simpler logic requirements. Each memory is sized to contain data supplied from specific instruments involved in given operating modes, thus simplifying the readout logic. Further details of the memory system are treated in the tradeoff section of this report.

Data compression is accomplished for the scanning type instruments by a zero-order-interpolator that discards redundant data, which are defined as lying within a given percentage of the last data point that exceeded the limits. A small buffer store retains the new data point and compares it to each of the succeeding samples. A sample that exceeds the limits replaces the one in the buffer store and is also placed in the memory.

Operational description. - During the first orbit, Group I science and engineering instruments, and the mass spectrometer are active and will be sampled six times. These data points are stored in core memory system "A," which is read out with the small drop sonde data when the orbiter comes within communication range.

Subsequent orbital periods have only the Group I science and engineering instrumentation active, which are sampled at a six times per orbit rate or approximately one sample per 0.75 hr. The mass spectrometer will be activated only on receipt of a Group II command. During any given readout period, the Group I science and engineering produces a real-time sample that is then followed by the stored data from the preceding orbital period; both real-time and stored data are read out a minimum of three times.

An assumed sequence of operations is shown in figures 23 and 24. It has been assumed that Groups II and III were commanded on at the start of the third orbit.

Succeeding orbital periods involve only the addition of Group III data for which a new sample is taken every third orbit. Upon receipt of a Group IIA/IIB command, one vidicon microscope photo and one biological laboratory sample will be taken each orbit, the data accumulation and transmission requirements are as shown in figure 25. At orbit 41, the last biological laboratory sample is read out, and the system returns to the Group I science and engineering and Group III readout cycle.

Drop sonde data replace Group III data whenever such operations are commanded. The data contributions are nearly identical and thus makes possible the sharing of memory system "C."

During descent, the data accumulation rises to 25 kilobits in memory system "A," thus either that memory must be sized for final descent data, or the data stored in memory system "D," which is inactive during the descent. The latter is the most attractive in that no excess memory capacity is required to satisfy a short time requirement. The data contributions per orbital period for the descent mode are given below:

Group I/science and engineering	4500 bits
Descent science (15 sec)	2100 bits
Descent science (5 samples)	140 bits
Descent engineering (15 sec)	2100 bits
Descent engineering (5 samples)	140 bits
Altimeter (5 samples)	70 bits
Mass spectrometer (4 samples)	16 000 bits
Light backscatter (5 samples)	350
Total for memory "A" or "D"	25 400
IR spectrometer (4)	40 000 bits memory "C"

The introduction of a cyclic mode requires some changes in the noncyclic station. The operation is similar to the descent mode described previously, four science and four engineering instruments are sampled at discrete pressure and temperature increments in addition to the normal time-based instrument samples. In addition, the descent instruments are sampled at a high rate immediately following the receipt of the cyclic mode command for a period of 15 sec and again on arrival at the minimum altitude. Data accumulations for the cyclic mode are as follows:

Initial science	2100 bits
Initial engineering	2100 bits
Descent science (20 samples)	560 bits
Descent engineering (20 samples)	560 bits
Minimum altitude science	2100 bits
Minimum altitude engineering	2100 bits
Ascent science (20 samples)	560 bits
Ascent engineering (20 samples)	560 bits
Altimeter	1400 bits
Total	12 040 bits

Communications Links

The command link plays a vital role in the success of the mission with the approach taken for this station. The station command receiver searches continuously for the orbiter command carrier until it locks on, this causes the station telemetry transmitter to be turned on. Meanwhile, the orbiter's receiver, which has been searching for the station transmitter signal, can now acquire the station's signal.

At lock on, the orbiter commands a ranging mode and then begins transmitting a PN ranging code for a fixed period to measure the round trip range to the station. The command to transmit telemetry data is then given and the station begins transmission of data to the orbiter. After a fixed interval, the orbiter commands another ranging measurement that continues until the maximum station transmitter "on" time has been reached or until the orbiter moves out of communications range. The station transmitter is turned off by the station central programer sequencer.

Station to orbiter link. - The station to orbiter telemetry link operates at 1000 BPS using 7-bit per word NRZ format during all data transmission modes. A 40-W, 400-MHz, solid-state transmitter is phase-modulated by the sum of two coherent subcarriers as shown in figure 26. The lower frequency subcarrier is modulated by a square wave at half the bit rate and the upper subcarrier that is twice the frequency of the lower subcarrier is modulated by the data.

At the receiving end, the carrier phase lock loop locks onto the incoming carrier, the lower frequency subcarrier is doubled and tracked using a phase lock loop to provide a VCO reference for demodulating the data subcarrier. Unambiguous bit sync is derived in the second phase lock loop and the data are recovered from the data channel using a matched filter (integrate and dump) as shown in figure 27.

The lowest frequency subcarrier operates at 16 KHz to allow an adequate band for the carrier search mode. If the subcarrier were placed too close to the carrier, the carrier loop could lock onto the subcarrier instead of the carrier.

Table 22 shows link margins, thresholds, system temperature, adverse tolerances and other link characteristics for a maximum range of 14 000 km. Table 23 is a tabulation of the engineering data transmitted over the link.

The station antenna is a quadrupole cavity-backed slot array located on the top of the gondola and arranged to give either hemispherical coverage or low elevation coverage depending on the phasing of the elements.

The antenna is described further in the analysis and tradeoff section of this volume.

Command link. - The command link operates at a frequency of 370 MHz and a bit rate of 50 BPS. The orbiter transmitter is solid state, with a power output of 20 W. For ranging (as shown later) 40 W is required.

Two subcarriers are used as in the station to orbiter telemetry link. The two-channel modulator and demodulator are identical in principle of operation to those for the telemetry link. The bit rate however is 50 instead of 1000 BPS.

The station receiver sweeps in search of the orbiter's command carrier, thus like the telemetry link the lowest frequency subcarrier must be placed well outside the sweep band to prevent the carrier tracking loop from locking onto the subcarrier or one of the modulation sidebands. Link calculations and characteristics are shown in table 24. The link margin under worst-case tolerance conditions maintains a maximum bit error probability of 1×10^{-5}.

Only real-time discrete commands have been identified as indicated by the command list, table 23. Therefore, no command storage has been provided in the station other than fixed time delays in initiation of sequences.

It appears that a fixed matrix decoder is the simplest design approach that is consistent with the PCM link constraints. This type of decoder consists essentially of a prewired, fixed logic matrix that decodes each received command word and supplies the appropriate switching function.

For reliable operation, a word frame structure of two address words followed by three command words is appropriate. Each address word is made up of two "ones" and four "zeros," whereas each command data word consists of four "ones" and four "zeros." If the words do not meet the above bit ratio criteria the command is rejected.

Ranging orbiter to station. - Ranging measurements between the orbiter and the station are made by using the command and telemetry links to provide a turnaround ranging capability.

Following two-way carrier lock, a repetitive command is transmitted to the station to switch the command receiver into the ranging mode. The orbiter then begins transmission of a PN ranging code, which is received by the station and retransmitted on the telemetry link. The time required for the spacecraft to acquire the code depends on the received code power, the desired error probability, and the composite code structure. Golomb (ref. 1) has shown the acquisition time can be minimized by using several subcode elements and acquiring the elements in sequence. For example, if three codes are being used of length p_1, p_2, and p_3, at most $p_1 + p_2 + p_3$ trials are required to acquire the code. If a single component code of the same length is used, the number of trials for acquisition would be $p_1 \times p_2 \times p_3$. Consequently, in the cases when acquisition time is to be reduced, a multiple component code should be used. The code length should also exceed twice the maximum round trip time to provide unambiguous range data.

For the particular case under consideration, the desired range accuracy is ±2 km. Therefore, the PN bit rate must be 37 700 BPS or a transmission rate of 18 750 Hz.

The ranging link calculations are shown in table 26. The 40-W down-link power is required to obtain an adequate SNR in the ranging channel and carrier tracking loop at apoapsis. It would be desirable to optimize the modulation index to ensure equal margins in the carrier and ranging channels. However, because of the variation in the ranging channel's modulation index with SNR, this is not possible. Consequently the maximum up-link modulation index was selected at 1.1 rad to ensure that carrier suppression does not take place under high SNRs. This would result in an equivalent ranging modulation index of 1.09 rad if the station happens to drift under periapsis. The up-link noise, which also modulates the transmitter, varies as the SNR in the ranging channel changes. This causes an increasing noise modulation loss on the up link as the down-link SNR decreases. For the link parameters presented in table 26, this has resulted in a 1.92 dB modulation loss because of noise.

The above difficulties can be avoided at the expense of station complexity and acquisition time by regenerating the code at the station. This would eliminate the variation of modulation index with range, the noise modulation problem, and would require less spacecraft transmitter power. However, it would be premature to postulate the requirement for this approach until detailed tradeoffs are made between the two systems.

Drop sonde-to-station link. - The drop sonde-to-station link operates at 25 BPS at a frequency of 300 MHz.

Noncoherent FSK is the modulation used. Separate mark and space filters followed by envelope detectors and a decision circuit are required to demodulate the signal. This is followed by bit by bit detection in the station, and the data are placed in the station core storage in a bit serial fashion.

The total number of bits transmitted and stored is a function of the time the drop sonde takes to reach the surface. Assuming 1 hr for descent time, the sonde will transmit 90 000 bits of data which are stored in a 90-kilobit core memory. In case of memory overflow, the new data will replace the old.

The sonde transmitter is solid state with a power output of 12 mW based on unity antenna gain. The link calculations are shown in table 27.

The bit rate indicated is adequate to handle data from the group of science instruments shown in table 4 plus sonde engineering data.

Telecommunications Size, Weight, and Power

Size, weight, and power requirements for the telecommunications subsystem are shown in table 28. The weights shown are farily conservative and do not reflect anticipated development in weight reduction over the next several years. However, one should anticipate allocating weight for the addition of redundant receivers, transmitters, etc., as required to improve the reliability of the subsystem.

Telecommunications Tradeoffs

Several approaches were considered in selecting the data management and telecommunications subsystem. These are discussed below.

Data Management Tradeoffs. -

Data accumulation and storage. - Large amounts of data are accumulated as a result of a Group II/Group III command. Examination of the data contributed by each of these instruments reveals a very large amount of redundancy is contributed by each. This indicates even the simplest form of data compression would produce significant reduction in the total data to be transmitted. Figure 28 illustrates the effect of a simple zero order interpolator (ZOI) on the total data collected per orbit with a worst-case compression ratio of 5:1. Data compression will then provide a maximum data transmission period requirement of less than 5 min for any given orbit as shown in table 29, and eliminate the requirement for a tape recorder since the data storage can be handled by core memory.

Group II instruments contribute 269 kilobits and Group III contributes 445 kilobits. The total data from one orbit, 718.5 kilobits, would require 35.9 min to be transmitted three times at 1 KBPS, which is impractical. Since Group III instruments take data only on every third orbit, those data could be read out only once during each communication period, which would reduce the transmission time to 21 min. Although communications periods at times in excess of 20 min can be foreseen, the minimum data transmission period available at times will be less than 5 min. Coupled to this is the problem of reading out a tape recorder. Under such conditions, a good portion of the tape recorder data would be lost since it is impractical to devise means to select a particular area of tape to be transmitted which was missed on a previous readout.

Another factor concerns Group IIB, which involves a series of 18 vidicon microscope photos; even if a photo is processed every other orbit, the transmission time would be excessive.

Analog-to-digital converters. - The selection of successive approximation type converters is based on the present developments of this technique in integrated circuits. There are many other techniques available that satisfy the station requirements, but none have received the attention given the successive approximation approach. The relative simplicity and stability derived from this type converter make it attractive for most spacecraft applications.

Communications tradeoffs. -

Modulation techniques and link integration. - An integrated telemetry, command, and ranging system was chosen as the better approach for several reasons:

1) A two-way radio link is required for telemetry and command purposes regardless of a ranging requirement;

2) A separate ranging link requires duplication of transmitters and receivers, additional frequency allocations, and an additional antenna or rf multiplexing into a broadband antenna;

3) Although simultaneous ranging command and data transmission may be desirable, excessive power would be required to operate two two-way links simultaneously.

A coherent PCM/PSK/PM telemetry link was chosen over a noncoherent link because of the need for a relatively high bit rate over a range of 14 000 km. Even with data compression, a telemetry bit rate of 1000 BPS seems the minimum required. To attain this rate at 400 MHz using noncoherent FSK, an effective radiated power of approximately 27 dBW would be required (assuming a +3 dB receive antenna gain). The 27 dBW (500 W) is, of course, not practical.

To complete the system PSK/PM using two subcarriers was chosen as the modulation technique for the command link. Two-way ranging occurs by replacing the command subcarrier modulation with a PN ranging code and relaying the received code over the telemetry link in place of the data subcarriers.

A look at the use of range tones (six tones and six tone phase lock loops) showed the system to be too complex.

For the command link, one needs a 20-W transmitter in the orbiter, but for ranging the rf power requirement goes to 40 W. Once the station transmitter is commanded on using the 20-W transmitter, the power can be stepped up to perform the ranging measurement.

Antennas. - Four antenna types were considered for the station/orbiter communication link. These are:

1) Planar log spiral-cavity backed antenna;
2) Crossed slot-cavity backed antenna;
3) Turnstile cup;
4) Phase array of four cavity backed slots.

A crossed dipole antenna above a ground plane was not considered because of the difficulties it presents during station deployment.

Of the four antennas listed, the phased array consisting of four cavity backed slots was selected as the most probable to be used for two reasons:

1) The elements can be placed such that they leave the center of the upper surface of the gondola free for installing the parachute and parachute deployment mortar in that area;
2) The antenna pattern may be changed on command from one giving hemispherical coverage to one giving low-angle coverage by a simple switching arrangement as shown in figure 29. With a low-angle coverage, one may realize an improvement in the link margins and hence the available communications time when the station has drifted far from the orbital plane.

The station antenna for reception of drop sonde data is a cavity backed cross slot. This choice was based on the desire to have a flush-mounted antenna so as not to obstruct the view of the science instrumentation and to eliminate any antenna deployment requirements.

Frequency selection. - Frequencies in the upper portion of the 200 to 400 Mc range were selected to get away from the 200-Mc region in which frequency allocations may be hard to obtain.

The higher frequencies, however, present somewhat of a penalty in added space loss and higher transmitter power.

POWER SUBSYSTEM

An analysis of the requirements of the subsystems making up the station results in a plot of cumulative energy needs as given in figure 30. As described in previous sections the regime of science experiments vary with individual orbits. The power requirements of Orbit 3, typical of one with high needs, is shown in figure 31.

Two kinds of power systems may be considered for the station. One, using a sterilized silver-zinc primary battery, will have a weight proportional to the mission life. The other using a radioisotope thermoelectric generator (RTG) will have a weight essentially independent of mission life, and will thus be essential for long missions.

Battery weight as a function of number of orbits in the mission, is given in figure 30, for a primary battery having a specific weight of 25 Wh/lb. With 6.3 orbits per Earth day, 5.6 kg (12.3 lb) of battery would be required for each day of operation.

The power subsystem would consist of an RTG, a battery, a charger, and a converter regulator. The converter regulator supplies the low-level continuously operating loads, while those having high peak demands are operated from the battery. Such an arrangement is shown in figure 32.

The energy supplied by the battery during Orbit 3 is as follows:

Science	
Group I	9.7 Wh
Group II	17.5
Group IIA (vidicon microscope)	2.5
Group III	7.9
Transmitter (operating 15 min)	25
	62.6 Wh

Of this amount, the battery may be required to supply one-fifth of Group I together with the other loads, without an intervening interval for recharge. Supplying this energy, totaling 54.4 Wh, requires a 35% depth of discharge from the battery. The voltage efficiency during the charge/discharge cycle is 85.5% and a 20% overcharge is needed for the nickel-cadmium battery. These factors, together with an 85% charger efficiency, result in 104 Wh required per orbit to maintain the battery. This results in an average of 27.2 W, which when added to the 9.4 W needed by the converter regulator, gives a total of 36.5 W. This requirement may be met by a 40-W RTG.

Table 30 summarizes information on the components making up the power subsystem. Note that the weight of the subsystem, excluding wiring and connectors, totals 28.4 kg. When applied to figure 30, it can be seen that this weight in a sterilized silver-zinc battery would permit operation for 31 orbits or 5 days. Thus, for periods beyond this time, an RTG system would be lighter. Engineering measurements are listed in Table 31.

THERMAL CONTROL SUBSYSTEM

The ambient temperature at equilibrium floatation 57 km in the mean density model is 225°K. In the extreme atmospheres, this environment may be from 195 to 287°K in the upper and lower density models, respectively. Batteries must be maintained at a minimum of 278°K, as well as other critical components and, therefore, require a thermal control subsystem. Superinsulation is used in conjunction with active power. For the cyclic station, the problem is one of cooling, requiring that a phase-change material (PCM) be considered in addition to insulation.

A thermal analysis was made for the mean model atmosphere for both the cyclic and noncyclic stations with the following assumptions:

1) Adiabatic surfaces between compartments;

2) Compartment external surface temperature equal to ambient temperature;

3) Ambient equilibrium temperature of 225°K;

4) Cycle ambient temperature increasing linearly to 620°K and decreasing linearly to 225°K in 4.25 hr;

5) Minimum allowable compartment temperature of 288°K;

6) Phase change material is "Eicosane" with melting point of 310°K (98°F), density (solid) of 53.3 lb/cu ft and latent heat of 106 Btu/lb;

7) Insulation is micro-quartz with conductivity of 0.02 Btu/hr-ft°R and density of 6 lb/cu ft;

8) Compartment equipment heat of 25 W.

For the noncyclic mission, 5 in. of insulation is required for the five compartments. This is a total weight of 193 lb. However, it should be noted that:

1) The gondola size could be significantly reduced in volume and, hence, the external surface area and insulation weight would be reduced accordingly;

2) The thermal energy of the RTG was not used in this analysis. With proper distribution of convection and radiation heat the insulation would again be reduced.

For the altitude cycling station, approximately 95 lb of the phase-change material is required with approximately 2 in. of insulation to maintain the equipment at 98°F. The protection required for the RTG is not included in this weight. Again if the gondola were reduced in size, increasing packaging to a moderate density, the surface area would be decreased, and the insulation weight would be decreased accordingly.

5000-POUND STATION

The 5000-lb station has been investigated to produce subsystem weight allocations. Figure 33 indicates that the 5000-lb station, using cryogenic hydrogen, is compatible with the Voyager capsule envelope. The weight allocations for the noncyclic station are shown in tables 32 and 33 for high-pressure and cryogenic hydrogen methods of transport, respectively. It is seen that gondola weights from 1900 lb to slightly more than 2800 lb are possible. This will allow for large, sophisticated payloads of the future. A cyclic station weight allocation is shown in table 34 for the gas dump and makeup mode. Decomposed hydrazine is used for the makeup gas system with separate tankage for each cycle. Obviously more than three cycles can be considered for this size station.

The largest balloon indicated is 340 000 cu ft with a diameter of 86.7 ft. For a 6-mb superpressure balloon, a film of approximately 3.8 mil, stressed to 6000 psi is required.

CONCLUSIONS

This station is the direct outcome of the original intent and constraints of the Buoyant Venus Station Feasibility Study, which specified a weight limit at deployment of 5000 lb. This is still the most attractive use of the balloon concept. The large payload and the mobility and long life make the station particularly suitable as a platform for the experiments of the relatively sophisticated and complicated scientific missions of the Voyager missions. Even if a true (survivable) lander were to prove feasible, it would not present the equivalent advantages of this station as a platform for experiments.

As this study makes clear, the 2000-lb weight is neither optimum or restrictive. In an earlier phase of this study 175 lb of scientific instrumentation (excluding drop sondes) was identified. This in one form or another related to practically all of the high-priority information desired about Venus. While this list in no manner exhausts the possibilities for experiments or instruments, it does suggest that a complement of three or four somewhat smaller stations -- say 1000 to 1500 lb -- for each Voyager bus would be reasonable. Similarly, it is equally reasonable to project a 5000-lb or larger station for as yet undefinable future missions. Two of the 2000-lb stations within a Voyager (Mars) aeroshell and envelope have been shown by way of illustration. Several smaller aeroshells (for separate entry and deployment) would also be appropriate for consideration.

The major development areas are (as with the 200-lb station) associated with the balloon and its controls. More leeway exists, however, in the solution of these problems in this case because of the reduced criticality of weight.

It is apparent that the noncyclic station could be reduced in size. However, it should be recognized that for this relatively complex mission, a degree of redundancy or other reliability enhancing techniques should be employed, which have not been considered in this study.

Martin Marietta Corporation
Denver Division
May 9, 1967

TABLE 1. - NONCYCLIC STATION WEIGHT SUMMARY

		Predeployment, lb	Postdeployment, lb
Parachute system		106	
Balloon system		274	200
Hydrogen system		850	70
Total payload			
Science	300		
Telecommunications	86	463	463
Power	77		
Margin[a]		307	307
		2000	1040

[a]To include structure and thermal control for gondola only.

TABLE 2. - CYCLIC STATION WEIGHT SUMMARY

		Predeployment, lb	Postdeployment, lb
Parachute system		106	
Balloon system		261	187
Hydrogen system		850	70
Cycle system		236	236
Total payload			
Science	300		
Telecommunications	86	463	463
Power	77		
Margin[a]		84	84
		2000	1040

[a]To include structure and thermal control for gondola only.

TABLE 3. - 2000-LB BVS EXPERIMENTS

No.	Experiment	Weight, lb	Power, W	Data acquisition
1	Temperature sensors (4)	2	.8	Two 7-bit words/measurement (range switched electronically)
2	Pressure sensors (10)	5	1.0	Four 7-bit words/measurement (2 ranges - 2 sensors/range)
3	Acoustic transmission	3	4	Four 7-bit words/reading Three readings/sample = 84 bits
4	Mass spectrometer (atmospheric gases)	10	10	4000 bits/analysis 60 sec/analysis
5	Pyrolysis/gas chromatograph/ mass spectrometer (cloud, dust composition)	15	15	10 000 bits/analysis 1 hr/analysis
6	Dust/cloud particle collector for 5	2	10 peak .5 cont	Status only
7	Vidicon microscope (dust and biota)	15	8	255 000 bits/picture 20 pictures/sample = 5.1×10^6 bits
8	Minimum bio lab	20	10 peak	100 hr/analysis 13 500 bits/analysis
9	Dust collector for 7 and 8	2	.5	Status only
10	Ion chamber and Geiger tube	3	.5	14 bits - ion chamber 21 bits - GM tube every 10 sec for 60 sec
11	Ultraviolet radiation flux	2	1.5	Six 7-bit words/measurement
12	Visible/near-IR flux	3	2.3	25 7-bit words/measurement
13	Altimeter/radar scatterometer	15	30	10 000 bits/10-sec scan 14 bits - altitude
14	Microwave scanner/spectrometer	25		100 000 bits/image 10 000 bits/scan, 4 wavelengths
15	IR scanner/spectrometer	10	4	255 000 bits/image 10 000 bits/scan, 4 wavelengths
16	Light backscatter from aerosols	5	5	10 7-bit words/sec
	Weight	137		

TABLE 4. - DROP SONDE EXPERIMENTS

Experiment	Weight, lb	Power, W	Data
Pressure sensors (5)	2.5	.5	Five 7-bit words
Temperature sensor (2)	1	.4	Two 7-bit words
Acoustic transmission line	3	4	Four 7-bit words
Mass spectrometer	10	10	4000 bits/analysis
Photometers, filters (looking up)	3	2.3	25 7-bit words
IR radiometer (looking down)	5	3	Four 7-bit words
Electrometer	1	1	One 7-bit word
Light backscatter from aerosols	2.5	2.5	Five 7-bit words

TABLE 5. - GROUP I MEASUREMENTS

Experiment	Data	Power, W-min
Pressure sensors (4)	Four 7-bit words	1
Temperature sensors (2)	Two 7-bit words	.8
Acoustic transmission line	Four 7-bit words	4
Altimeter	Five readings over 5 min; 14 bits per reading	100
Visible/IR flux	25 7-bit words	2.3
Ultraviolet flux	Six 7-bit words	1.5
Ion chamber and GM tube	Count for 60 sec; 14 bits every 10 sec for ion chamber, 21 bits every 10 sec for GM tube	.5

TABLE 6. - GROUP II MEASUREMENTS

Experiment	Data	Power, Wh
Mass spectrometer	4 000 bits/60 sec	1/3
Pyrolysis/GC/MS	10 000 bits/hr	15
Vidicon microscope (one picture)	255 000 bits	1.2
Group IIA		
Vidicon microscope (17 pictures)	255 000 bit/picture (4 335 000 bits)	8 W for 17 min = 2.26 Wh
Group IIB		
Bio lab	450 bits/reading one reading per orbit for 28 orbits, 2 readings in first orbit (13 500 bits total)	10 W for 3 min = 0.5 Wh/orbit

TABLE 7. - GROUP III MEASUREMENTS

Experiment	Data	Power, W-min
Radar scatterometer	10 000 bits per 10 sec scan	20
Microwave scanner/ spectrometer	100 000 bits/image 10 000 bits/scan 4 wavelengths (140 000 bits)	200 (warmup) + 26
IR scanner/spectrometer	255 000 bits/image 10 000 bits/scan 4 wavelengths	225

TABLE 8. - GROUP IV MEASUREMENTS

Experiment	Data	Power, W-min
Group I	As in table 3	
Mass spectrometer	4000 bits	20
IR scanner/spectrometer	56 bits/sample during descent; 255 000 bits at minimum altitude	5 25
Light backscatter from aerosols	70 bits/sec for 1 min	5

TABLE 9. - BALLOON INFLATION HARDWARE

Item	Quantity	Unit weight, lb	Unit volume, cu in.	Unit energy requirement	Total weight, lb	Total volume, cu in.	Total energy
Pressure switch	3	.3	3	None	.9	9	None
Timer	2	.4	.5	28 Vdc, .05 A, 10 sec	.8	1.0	28 W-sec
Ordnance squib	9	.07	.5	28 Vdc, 5 A, 0.25 sec	.65	4.5	33 W-sec
Ordnance valve	2	.15	2	None	.3	4	None
Pin puller	1	.4	2	None	.4	2	None
Guillotine	1	.15	3	None	.2	3	None
Explosive nut	4	.5	3	None	2.0	12	None
Flowmeter (orifice-pressure transducer)	1	.2	1	None	.2	1	None
Battery (thermal)	2	.5	3	1000 W-sec	1.0	6	5 Wh
Pressure transducer[a]	2	.27	3	28 Vdc, .01 A, 180 sec	.55	6	100 W-sec
Temperature transducer[a]	2	.02	2	28 Vdc, .04 A, 180 sec	.05	4	400 W-sec
Tubing, fittings, wiring, and connectors	-	-	-	None	5.0	-	None
Hand fill valve	1	.25	3	None	.25	3	None
Filter	1	.10	2	None	.10	2	None
Solenoid valve	1	1.50	10	28 Vdc, .5 A	1.50	10	420 W-sec
				Totals	13.9	68	986 W-sec

[a]For engineering measurements only.

TABLE 10. - BALLOON INFLATION HARDWARE STATUS

Item	Characteristic	Flight usage	Development status	Remarks
Pressure switch	6 ± 2 mb	None	On drawing board	Feasible for 1970 time period
Pressure switch (orifice meter)	.1 ± 0.5 psid	Unknown	Unknown	Well within state of art
Timer	R-C circuit	Titan III	Qualified as used	
Ordnance squib Ordnance valve	Sterilizable	Mariner, Surveyor	Passed sterilization tests	
Guillotine	Sterilizable	Titan III	Qualified as used	
Explosive nut	Sterilizable	Titan III		
Battery (thermal)	Sterilizable	B-57, weapon systems		
Pressure transducer	0 to 4500 psia	Mariner, Surveyor		
Temperature transducer	100 to 400°K	Mariner, Surveyor		
Manual fill valve	Sterilizable	Mariner, Surveyor		
Filter	10 μ	Mariner, Surveyor		
Solenoid valve	Sterilizable	Mariner, Surveyor	Qualified as used	
Relief valve	6-mb cracking pressure	None	None	A development and qualification program is required

TABLE 11. - REQUIREMENTS FOR A RELIEF VALVE

Cracking pressure	6-mb differential pressure[a]
Full flow pressure	10-mb differential pressure[b] Flow rate: 1.00 lb/sec hydrogen at T = 225°K P = 110 mb
Reseat pressure	4-mb differential pressure
Leakage	Maximum of 10 scc/sec of hydrogen at reseat pressure and temperature of 225°K
Temperature	Operating 195 to 300°K Nonoperating 195 to 675°K
Acceleration	Operating 1.0 (Earth) g Nonoperating 500 (Earth) g for 3 sec
Sterilization	The valve shall be capable of being sterilized

[a]Based on 6 mb producing a fabric stress of 6000 psi. Mylar yield is 12 000 psi, Kapton yield is 10 000 psi, and PBI yield is 22 000 psi.

[b]Full flow rate is based on relief valve ability to handle filling rate.

TABLE 12. - CYCLIC 2000-LB STATION GAS DUMP AND MAKEUP HYDRAZINE CYCLE SUBSYSTEM (3 CYCLES TO 10 KM, 6-MB SUPERPRESSURE HYDROGEN-INFLATED BALLOON 57 KM IN MEAN ATMOSPHERE)

Parachute and deployment hardware weight		106 lb
Parachute diameter	75.5 ft	
Deployed by mortar		
Balloon		
Volume	94 400 cu ft	
Diameter	56.6 ft	
Surface area	10 050 sq ft	
Balloon (PBI film)	170 lb	
Risers and attachments	17 lb	
Balloon canister	74 lb	
	Weight	261 lb
Hydrogen inflation		
Gas for balloon inflation	69.4 lb	
Gas residual in tank	.1 lb	
Gas tank	765.0 lb	
Controls, valving, etc.	15.5 lb	
	Weight	850 lb
Hydrazine cycle subsystem		
First cycle		
Gas	65.5 lb	
Residual gas	3.3 lb	
Tankage	7.0 lb	
Controls, valving, etc.	6.2 lb	
Second cycle		
Gas	63.0 lb	
Residual gas	3.2 lb	
Tankage	6.8 lb	
Controls, valving, etc.	6.0 lb	
Third cycle		
Gas	59.5 lb	
Residual gas	3.0 lb	
Tankage	6.5 lb	
Controls, valving, etc.	6.0 lb	
	Weight	236 lb
Gondola		
	Weight	547 lb
Weight lofted (initial)		
Balloon	187 lb	
Gas	70 lb	
Cycle subsystem	236 lb	
Gondola	547 lb	
	Total weight lofted	1040 lb
Buoyancy (initial)		1040 lb

TABLE 13. - BALLOON CYCLE HARDWARE, GAS DUMP AND MAKEUP, HYDRAZINE SYSTEM

Item	Quantity	Unit weight, lb	Unit volume, cu in.	Unit energy requirement	Total weight, lb	Total volume, cu in.	Total energy, W-sec
Timer	1	.4	.5	28 Vdc, .05 A, 70 sec	1.2	1.5	98
Ordnance squib	8	.07	.5	28 Vdc, 5 A, .025 sec	.6	4	28
Ordnance valve	3	.15	2	None	.5	6	None
Explosive nut	4	.5	3	None	2.0	12	None
Guillotine	1	.15	3	None	.2	3	None
Catalyst chamber	1	4.0	150	None	4.0	150	None
Pressure transducer[a]	1	.27	3	28 Vdc, .01 A, 180 sec	.55	6	100
Temperature transducer[a]	1	.02	2	28 Vdc, .04 A, 180 sec	.05	4	400
Tubing, fittings, wiring, and connectors	-	-	-	None	1.0	-	None
Manual fill valve	2	.25	3	None	.5	6	None
Filter	1	.10	2	None	.10	2	None
				Totals	10.7	194.5	626

[a]For engineering measurements only.

TABLE 14. - BALLOON CYCLE HARDWARE STATUS

Item	Characteristic	Flight usage	Development status	Remarks
Timer	Mechanical	Mariner	Qualified as used	
Ordnance squib	Sterilizable	Mariner, Surveyor	Qualified as used	
Ordnance valve	Sterilizable	Mariner, Surveyor	Qualified as used	
Explosive nut	Sterilizable	Launch vehicles	Qualified as used	
Guillotine	Sterilizable	Launch vehicles	Qualified as used	
Catalyst chamber	Shell 405 catalyst	None	In development	Can be qualified for this mission
Pressure transducer	0 to 1000 psia	Mariner, Surveyor	Qualified as used	
Temperature transducer	100 to 400°K	Mariner, Surveyor	Qualified as used	
Manual fill valve	Sterilizable	Mariner, Surveyor	Qualified as used	
Filter	10 μ	Mariner, Surveyor	Qualified as used	

TABLE 15. - ENGINEERING MEASUREMENTS FOR STATION DEPLOYMENT AND NONCYCLIC STATION BALLOON MONITORING

Measurement	Range	Desired accuracy
Total pressure	0 to 50 mb	±2%
Static pressure	0 to 500 mb	±2%
Total temperature	100 to 800°K	±5%
Inflation gas tank pressure	0 to 350 000 mb	±5%
Inflation gas tank temperature	100 to 400°K	±5%
Inflation gas flow rate	0 to .5 lb/sec	±2%
Balloon pressure	0 to 25 mb	±2%
Balloon gas temperature	100 to 400°K	±5%
Vernier gas tank pressure	0 to 70 000 mb	±5%
Vernier gas tank temperature	100 to 400°K	±5%
Cyclic station (in addition to those above)		
Cycle gas tank pressure	0 to 70 000 mb	±5%
Cycle gas tank temperature	100 to 800°K	±5%

TABLE 16. - TRADE STUDIES

Inflation gas	Balloon materials	Cycle method
Hydrogen	Mylar	Gas dump and makeup
High-pressure gas	Kapton	Gas dump and ballast drop
Cryogenic fluid	PBI	
Hydrazine		Pump and dump atmospheric gases

TABLE 17. - NONCLYCLIC 2000-LB STATION, HYDROGEN GAS, 6-MB SUPERPRESSURE, 57 KM IN MEAN ATMOSPHERE

Parachute and deployment hardware weight		106 lb
Parachute diameter	75.5 ft	
Deployed by mortar		
Balloon		
Volume	94 400 cu ft	
Diameter	56.6 ft	
Surface area	10 050 sq ft	
Balloon fabric	183.0 lb	
Risers and attachments	17.0 lb	
Balloon canister	74.0 lb	
	Weight	274 lb
Hydrogen inflation		
Gas for balloon inflation	69.4 lb	
Gas residual in tank	.1 lb	
Gas tank	765.0 lb	
Controls, valving, etc.	15.5 lb	
	Weight	850 lb
Gondola		
	Weight	770 lb
Weight lofted		
Balloon	200 lb	
Gas	70 lb	
Gondola	770 lb	
	Total weight lofted	1040 lb
Buoyancy of station		1040 lb

TABLE 18. - NONCYCLIC 2000-LB STATION, DECOMPOSED HYDRAZINE GAS, 6-MB SUPERPRESSURE, 57 KM IN MEAN ATMOSPHERE

Parachute and deployment hardware weight		106 lb
Parachute diameter	75.5 ft	
Deployed by mortar		
Balloon		
Volume	150 000 cu ft	
Diameter	66 ft	
Surface area	13 670 sq ft	
Balloon fabric	290 lb	
Risers and attachments	20 lb	
Balloon canister	100 lb	
	Weight	410 lb
Hydrazine inflation subsystem		
Decomposed hydrazine in balloon	702 lb	
Residuals in tankage	35 lb	
Tankage	74 lb	
Controls, valving, etc.	19 lb	
	Weight	830 lb
Gondola		
	Weight	654 lb
Weight lofted		
Balloon	310 lb	
Gas	702 lb	
Gondola	654 lb	
	Total weight lofted	1666 lb
Buoyancy of station		1666 lb

TABLE 19. - BALLOON MATERIALS

Material	Tensile strength, psi, at temperature of:			Operating temperature range, °K	Specific gravity
	298°K	473°K	573°K		
Mylar	23 000	7 000		4 to 423	1.40
Kapton	25 000	17 000		4 to 675	1.42
PBI	22 500	20 000	14 700	Up to 723	1.30

TABLE 20. - SEQUENCE OF OPERATION, 2000-LB STATION (NONCYCLIC)

Orbit/step	Operation	Initiated by
	Phase A - separation from aeroshell through the deployment phase	
1-A1	Blow station/aeroshell separation bolts	Aeroshell
1-A2	Start station central programer/sequencer Activate thermal battery for pyrotechnics Arm station ordnance Start transmission of deployment engineering data Turn on command receiver and decoder	Aeroshell
1-A3	Mortar deploys parachute	Deployment controls package (DCP)
1-A4	Release balloon retainer ring	DCP
1-A5	Open inflation gas valve	DCP
1-A6	Close inflation gas valve	DCP
1-A7	Sever balloon inflation line	DCP
1-A8	Release tankage and parachute	DCP
1-A9	Transmitter turn off	Central programer/sequencer (CPS)
	Phase B - equilibrium floatation	
1-B1	Open vernier gas isolation valve (ordnance	Timer or command (1-hr after tank release)
	Phase C - beginning of science measurements	
1-C1	Deploy dust collector	CPS
1-C2	Initiate checkout of science instrumentation; store engineering data	CPS
1-C3	Start sampling Group I instrumentation and store data every 3/4 hr (store in core memory A)	CPS
1-C4	Make atmospheric composition and store data (1 measurement)(store in core memory A)	CPS
1-C5	Initiate sequence for drop of small sonde Turn on sonde power Turn on station receiver (standby) Store 2 frames of sonde data in station storage Release sonde Place station sonde receiver in "on" receive and store sonde data in core memory C	CPS
1-C6	Turn off sonde receiver	CPS
	End first orbit - begin second orbit (when orbiter comes into view)	
2-1	After two-way carrier lock between orbiter and station; begin ranging measurement	Orbiter command (OC)
2-2	End ranging measurement	OC
2-3	Begin transmission of data to orbiter in following sequence 1) Data preamble 2) Real-time Group I science and engineering 3) Memory A contents (engineering, Group I science + mass spectrometer data) 4) Memory C contents (drop sonde data)	OC or CPS
2-4	Begin ranging measurement	OC
2-5	End ranging measurement	OC or CPS
2-6	Command transmitter off	OC

TABLE 20. - SEQUENCE OF OPERATION, 2000-LB STATION (NONCYCLIC) - Continued

Orbit/step	Operation	Initiated by
2-7	If command not received, turn off transmitter (based on maximum time programed to be on)	CPS
	Reset timing for making 3/4 hr Group I measurement	
2-8	Continue to make Group I and engineering samples every 3/4 hr	CPS
	Note: Transmit data to earth from orbiter for quick-look evaluation (as early as possible)	Earth command
	End orbit 2 - begin orbit 3	
3-1	Perform ranging operation (orbiter/station)	OC
3-2	Transmit data to orbiter	OC
	Real-time engineering and Group I - followed by contents storage A	
	Command station to initiate Group II and Group III science measurements (to begin after this communications pass)	OC
3-3	Perform ranging operation	OC
3-4	Turn off transmitter	OC or CPS
3-5	Sample Group I + engineering every 3/4 hr and store in core storage A	CPS
	Sample Group II and store in core storage B	CPS
	Sample Group III and store in core storage C	CPS
	End orbit 3 - begin orbit 4	
4-1	Perform ranging operation	OC
4-2	Begin transmission of data	OC or CPS
	Preamble	
	Real-time Group I, real-time engineering 1 frame	
	Storage A (3 times)	
	Storage B (3 times)	
	Storage C (once)	
	Storage D (3 times)	
4-3	Perform ranging operation	OC
4-4	Transmitter off	OC or CPS
4-5	In absence of commanded mode change, continue sampling Group I and engineering every 3/4 hr	CPS
	Store in core storage A	
	Retain memory C data	
	End orbit 4 - begin orbit 5	
	Orbit 5 same as orbit 4 except no readout of memory B or D	OC and CPS
	End orbit 5 - begin orbit 6	
6-1	Perform ranging operation	OC
6-2	Command begin of vidicon microscope (IIA) and bio lab (IIA) processing	OC
	Store bio lab data in storage A	
	Store vidicon microscope picture in memory D	
	Store new Group III data in memory C (This processing starts after transmitter is shut down in Step 6-5)	

TABLE 20. - SEQUENCE OF OPERATION, 2000-LB STATION (NONCYCLIC) - Continued

Orbit/step	Operation	Initiated by
6-3	Transmit data to orbiter Real-time Group I and engineering followed by memory A and third repeat of memory C (memory A also has baseline bio lab data)	OC or CPS
6-4	Perform ranging operation	OC
6-5	Shut down transmitter	OC or CPS
6-6	Begin sampling and store of Group I and engineering every 3/4 hr Group III Group IIA and IIB	 CPS (as result of Step 6-3)
End orbit 6 - begin orbit 7		
7-1	Perform range measurement	OC
7-2	Transmit data to orbiter in following order Preamble Real-time Group I and engineering Core memory A, B, C, and D (memory A, B, and D are repeated 3 times to one of C) Note: Contained in this data is Group I, the second vidicon microscope photo of a series of 18, the first bio lab sample following the reference sample, and a new set of Group III data	OC or CPS
7-3	Perform ranging	OC
7-4	Turn off transmitter The mission sequence continues under the following conditions 1) The bio lab IIB once started is sampled once per orbit and the data is stored in core storage A along with Group I and engineering - it is transmitted at the beginning of the next orbit 2) The vidicon-microscope takes 1 picture per orbit for 17 consecutive orbits; the data for 1 picture are stored in memory D and transmitted at the beginning of the following orbit at least 3 times 3) A large drop sonde may be commanded to be released on a given orbit in place of Group III data. The sonde data are then placed in memory C in place of Group III data. The sonde data are initially transmitted on the following orbit and repeated on the following two orbits 4) The last vidicon microscope picture is transmitted at the beginning of the 23rd orbit 5) The last bio sample is transmitted on the 41st orbit 6) The entire cycle, orbits 3 thru 42, can be repeated by commanding Group II data in orbit 45. See orbit 3 for beginning of new sequence. 7) The final descent mode is described below.	OC or CPS

TABLE 20. - SEQUENCE OF OPERATION, 2000-LB STATION (NONCYCLIC) - Concluded

Orbit/step	Operation	Initiated by
Phase D - final descent, begin orbit No. N		
N-D1	Two-way carrier lock-orbiter/station	Orbiter
N-D2	Perform ranging measurement	OC
N-D3	Command station descent - (delayed initiation) Group IV science mode of sampling	OC
N-D4	Transmit data remaining in storage	CPS
N-D5	Perform ranging measurement	OC
N-D6	Turn off station transmitter	OC or CPS
N-D7	Relase balloon gas	CPS
N-D8	Begin sampling and storing Group IV data and engineering data	CPS
End orbit N - begin orbit N + 1		
(N+1)-D1	Perform ranging	OC
(N+1)-D2	Transmit stored Group IV data and engineering data	OC or CPS
(N+1)-D3	Perform ranging	OC
(N+1)-D4	Turn off station transmitter	OC or CPS
End orbit N+1 - begin orbit N+2		
	Continue same sequence as for previous orbit for this orbit and for additional orbits until station ceases to operate or until communications can no longer be established	
	Note: 1. Group III science instrument data are stored in core memory (C). These data are sampled once every third orbit, and it takes 3 orbits to obtain 3 transmissions of the same picture. 2. One bio lab sample will be placed in memory A beginning with a Group IIB command and will continue to sample on a once per orbit basis for 35 orbits.	

TABLE 21. - SEQUENCE OF OPERATION, 2000-LB STATION (CYCLIC)[a]

Orbit/step	Operation	Initiated by
45-1	Perform ranging function	Orbiter command (OC)
45-2	Transmit data accumulated during orbit 44	OC or CPS
45-3	Command descent mode (delay initiation)	OC
45-4	Perform ranging function	OC
45-5	Turn off station transmitter	OC or CPS
45-6a	Release increment of gas from balloon and begin descent	CPS (as result of command)
b	Sample engineering data at high rate for 15 sec and store	CPS
c	After 15 sec sample data once per increment of temperature or atmospheric pressure change and store as station descends Sample and store Group IV science data	CPS
	End orbit 45 - begin orbit 46	
46-1	Perform ranging operation	OC
46-2	Transmit stored data to orbiter	OC or CPS
46-3	Perform ranging operation	OC
46-4	Turn off transmitter	OC or CPS
46-5a	At minimum altitude programed or if temperature threshold is exceeded add makeup gas to start ascent and drop cyclic gas storage tank	Altimeter or temperature sensor signal to CPS
b	Sample and store engineering instrument data at high rate for 15 sec	Altimeter or temperature sensor signal to CPS
c	After 15 sec, sample engineering and Group IV science at fixed increments of temperature or atmospheric pressure change	CPS
	End orbit 46 - begin orbit 47	
47-1	Perform ranging measurement	OC
47-2	Transmit data to orbiter	OC or CPS
47-3	Command Groups II and III data mode sampling to begin after transmitter turn off (assuming station has reached proper altitude) or command some other data sampling mode in accordance with mission plan	OC
47-4	Perform ranging	OC
47-5	Turn off transmitter	OC or CPS
47-6	Begin sampling and store per command of Step 47-3	CPS

[a]The sequence of operation for the cyclic station is basically the same as for the noncyclic station except for the initial deployment (in which the cycle gas isolation valve must be opened when the vernier gas isolation valve is opened) and for orbits in which a descent and ascent cycle is commanded. For such a cycle the sequence shown applies assuming it occurs on orbit 45.

TABLE 22. - TELEMETRY LINK CALCULATION

Total transmitter power	46	dBm
Antenna gain product ($G_T G_R$)	3.0	dB
Space loss (400 MHz at 14 000 km)	-167.37	dB
Receiver circuit loss	-1.00	dB
Polarization loss	-1.00	dB
Transmitter circuit loss	-0.5	dB
Ionospheric attenuation	-1.0	dB
Multipath fading	0.0	dB
Total received power	-121.87	dBm
System sensitivity (N.F. = 3 dB, T_a = 965°K)	-167.6	dBm/Hz
Carrier performance		
Modulation loss	-8.70	dB
Threshold SNR	8.70	dB
APC noise bandwidth (160 MHz)	22.04	dB
Threshold carrier power	-136.86	dBm
Received carrier power	-130.57	dBm
Margin	6.29	dB
Data channel performance		
Modulation loss	-1.43	dB
Bit rate (1000 BPS)	30.0	dB
Required ST/(N/B) $P_e{}^b = 5 \times 10^{-3}$	8.0	dB
Threshold data power	-129.6	dBm
Received data power	-123.3	dBm
Margin	6.30	dB
Sync channel performance		
Modulation loss	-16.38	dB
Threshold SNR	20.0	dB
APC noise bandwidth $(2\beta_{Lo} = 2\ Hz)$	3.0	dB
Threshold sync power	-144.60	dBm
Received sync power	-138.25	
Margin	6.35	dB
Summary of adverse tolerances		
Polarization loss	.5, -1.5	dB
Receiver circuit loss	±.5	dB
Transmitter circuit loss	0.0, -.5	dB
Ionospheric attenuation	±.5	dB
Multipath fading	±2.0	dB
Total	3.5, -5.0	dB

TABLE 23. - ENGINEERING DATA

Measurement	Bits/sample	Accuracy, percent	Sampling rate		
			Deploy	Floatation	Cycling or descent
Static pressure	7	±2	5/sec		
Total pressure		±2	5/sec		
Total temperature		±5	1/sec		
Gas tank pressure		±5	1/sec		
Gas tank temperature		±5	1/sec		
Gas flow rate		±2	3/sec		
Sonde compartment temperature 1		±10	1/sec	1/1.5 hr	Same as for floatation mode
Sonde compartment temperature 2		±10			
Station science package temperature 1		±10			
Station science package temperature 2		±10			
Station science package temperature 3		±10			
Station science package temperature 4		±10			
Station science package temperature 5		±10			
Station science package temperature 6		±10		1/1.5 hr	
Balloon differential pressure		±5		1/3/4 hr	5/sec [a]
Balloon gas temperature		±1		1/3/4 hr	5/sec
Balloon absolute pressure		±1			5/sec
Vernier gas tank pressure		±5			5/sec
Vernier gas tank temperature	7	±5		1/3/4 hr	Same as for floatation mode
Cycle gas tank pressure 1	[b]7	±5		1/1.5 hr	
Cycle gas tank pressure 2	[b]7	±5			
Cylce gas tank pressure 3	[b]7	±5			
Cycle gas tank temperature 1	[b]7	±5			
Cycle gas tank temperature 2	[b]7	±5			
Cycle gas tank temperature 3	[b]7	±5	1/sec	1/1.5 hr	
Seven discretes (deployment events)	7	On/off	5/sec	--	--
+6 voltage		±5		1/1.5 hr	Same as for floatation mode
-12 Voltage		±5			
+5 voltage		±5			
RTG current out		±5			
RTG voltage out		±5	5/sec		
RTG temperature		±10	1/sec		
Battery charge current		±3	1/sec		
Battery voltage (fine)		±1	5/sec		
Battery voltage (coarse)		±3	5/sec		
Battery output current		±5	1/sec		
Converter regulator temperature		±10			
Battery temperature		±10			
Science Group I current		±5			
Science Group II current		±5			
Science Group III current		±5			
Drop sonde battery voltage 1		±5			
Drop sonde battery voltage 2		±5			
Drop sonde battery voltage 3		±5			
Drop sonde battery voltage 4		±5			
Drop sonde battery voltage 5		±5			
Transmitter internal temperature		±10			
Transmitter output (rf)		±10			
Power amplifier current		±10	1/sec		
Receiver AGC voltage		±10	5/sec		
Receiver internal temperature		±10	1/sec		
Receiver VCO output		±10	1/sec		
Command subcarrier demod		±5	5/sec		
VCO output 1		±5	5/sec		
VCO output 2					
Command decoder (internal temperature)		±10	1/sec		
Command status (7 discretes)		On/off	5/sec		
Command status		On/off	5/sec		
Reflected rf power		±20	5/sec		
Analog reference voltage		-	5/sec		
Master oscillator temperature		±10	1/sec		Same as for floatation mode
Station sonde receiver temperature		±10			
Station sonde receiver AGC voltage	7	±10			
Station clock time	21	1 bit	1/sec	1/1.5 hr	Once per frame

[a]5/sec sampling rate for 15 sec at start ascent and descent.

[b]For cyclic station only.

TABLE 24. - COMMAND LINK CALCULATION

Transmitter power	43.0	dBm
Antenna gain product	3.0	dB
Space loss (370 MHz at 14 000 km)	-167.03	dB
Receiver circuit loss	-1.00	dB
Polarization loss	-1.00	dB
Transmitter circuit loss	-.50	dB
Ionospheric attenuation	-1.00	dB
Multipath fading	0.0	dB
Total received power	-124.53	dB
System sensitivity (2000°K)	-165.6	dBm
Carrier performance		
Modulation loss	-2.52	dB
Threshold SNR	8.70	dB
APC noise bandwidth	22.04	dB
Threshold carrier power	-135.06	dBm
Received carrier power	-127.05	dBm
Margin	8.01	dB
Data performance		
Modulation loss	-5.30	dB
Bit rate (50 BPS)	17.0	dB
Required ST/(N/B) $P_e^b = 10^{-5}$	11.0	dB
Threshold data power	-137.60	dBm
Received data power	-129.83	dBm
Margin	7.77	dB
Sync performance		
Modulation loss	-10.20	dB
Threshold SNR	20.0	dB
APC noise bandwidth	3.0	dB
Threshold sync power	-142.60	dBm
Received sync power	-134.73	dBm
Margin	7.87	dB

TABLE 25. - COMMANDS, CYCLIC OR NONCYCLIC, 2000-LB STATION

Command	Remarks
1. Initiate sequence for test and release of drop sonde	
2. Initiate final descent mode sequence	Must be immediately preceded by command 26
3. Start transmitting data	
4. Inhibit turn on a power to Group I science	
5. Enable turn on of power to Group I science	
6. Inhibit turn on of power to Group II science	
7. Enable turn on of power to Group II science	
8. Inhibit turn on of power to Group III science	
9. Enable turn on of power to Group III science	
10. Enable turn on of all science (comes on as programed or modified by other commands)	
11. Inhibit turn on of all science (if on turn off)	
12. Maximum transmitter operating time 10 min	
13. Maximum transmitter operating time 15 min	
14. Maximum transmitter operating time 20 min	
15. Start science Group II and III sample and store	
16. Start Group IIA and IIB science processing and store	Must be preceded by command 15
17. Reset sequencer	
18. Begin ranging mode	
19. End ranging mode	
20. Switch to overhead antenna pattern	
21. Switch to low elevation antenna pattern	
22. Dump increment of inflation gas from balloon	
23. Open vernier gas isolation valve	Backup
24. Add fixed increment of gas	
25. Drop ballast (if temperature is too high)	Backup
26. Enable receipt of final descent mode command	
27. Inhibit receipt of final descent mode	(27 countermands 26)
28. Spare command for isolation of additional power consumers or redundancy switching	
29. Spare command for isolation of additional power consumers or redundancy switching	
30. Change station transmitter turn on threshold to A setting	
31. Change station transmitter turn on threshold to B setting	
Additional commands - for cyclic station only	
32. Open cyclic gas isolation valve	Backup
33. Begin cyclic descent station sequence	
34. Set minimum altitude for cycle reversal at 10 km	
35. Set minimum altitude for cycle reversal at 15 km	
36. Set minimum altitude for cycle reversal at 20 km	

TABLE 26. - TURNAROUND RANGING

Down link		
Transmitter power	46	dBm
Antenna gain product	3	dB
Total miscellaneous losses	-3.5	dB
Space loss (370 MHz at 14 000 km)	-167.03	dB
Total received power	-121.53	dBm
Receiver noise spectral density	-165.6	dBm/Hz
Receiver bandwidth	51.3	dB
Total received SNR ($1/\beta$)	-7.23	dB
Limiter signal suppression factor	.129	
$\sigma s^2 = 1 \Big/ \left(1 + \frac{4}{\pi}\beta\right)$		
Limiter noise suppression factor	.726	
$\sigma n^2 = \beta/(\beta + 2)$		
Up link		
Total transmitter power	46	dBm
Antenna gain product ($G_T G_R$)	3	dB
Total miscellaneous losses	-3.5	dB
Space loss (400 MHz at 14 000 km)	-167.37	dB
Total received power	-121.87	dBm
Receiver noise spectral density	-167.6	dBm/Hz
Carrier performance		
Modulation loss $\left(\beta_R = 0.397,\ \sigma n^2 = 0.475\right)^a$	-2.66	dB
Threshold SNR	8.70	dB
APC noise bandwidth	22.0	dB
Threshold carrier power	-136.9	dBm
Received carrier power	-124.2	dBm
Margin	12.7	dB
Ranging performance		
Modulation loss $\left(\beta_R = 0.397,\ \sigma n^2 = 0.475\right)^a$	-10.88	dB
Threshold SNR	22.0	dB
APC noise bandwidth	3.0	dB
Threshold ranging power	-142.6	dBm
Received ranging power	-132.4	dBm
Margin	10.2	dB

[a]Based on strong signal β_R = 1.09 rad at closest approach.

TABLE 27. - DROP SONDE-TO-STATION LINK, FSK SPLIT PHASE

System losses	5.0 dB	
Adverse tolerance	4.5 dB	
Space loss (100 km)	122.5 dB	300 MHz
Total losses	132.0 dB	
Receiver noise/cycle	-167.4 dBm	
Receiver bandwidth rf	44.0 dB	25 KHz
System noise power	-123.4 dBm	
Required SNR in	2.15 dB	25 dB SNR out
Required signal power	-121.25 dBm	
Losses	-132.0 dB	
Required transmitter power (for 0 dB antenna gain power)	10.75 dBm	
or	12 mW	

TABLE 28. - TELECOMMUNICATIONS SIZE, WEIGHT, AND POWER SUMMARY

Unit	Power, W		Weight, lb	Size	Comments
	Standby	On			
Command receiver	1	1	4.2	2.9x7x6.15 in.	
Command decoder	.030	2	6	350 cu in.	"Power on" during commanding only
Diplexer	-	-	2	5.7x1.8x2.6 in.	
Main vhf antenna	-	-	8		Four cavity backed slots
Sonde vhf antenna	-	-	6		Crossed slot cavity backed
Transmitter		100	13.5	12x6x3 in.	40-W solid state
Data package 1		1.53	2	31.5 cu in.	
Data package 2		2.15	5	98.5 cu in.	
Data package 3		1.25	1.5	84 cu in.	
Data selector		.075	.8	75 cu in.	
Programer/sequencer		1.0	1	6x6x3 in.	
Group I memory (A)		.150	2	75 cu in.	
Group II memory (B)		.150	2	75 cu in.	
Group III/memory (C)		.750	15	500 cu in.	
Group IIA memory (D)		.750	15	500 cu in.	
Receiver (sonde data)	.085	.170	1	100 cu in.	
Bit synchronizer (sonde data)		1.0	1	100 cu in.	
Total			86.0 lb		

TABLE 29. - DATA ACCUMULATION AND REQUIRED DATA TRANSMISSION TIME PER ORBIT

Orbit	Data group	Bits x 1000	No. readouts	Sample no.	Transmission time, min, at 1 KBPS	Remarks
1	Deploy engr	Transmit at 1000 BPS for 20 min.				Real-time deploy
2	MS	4.0	3	-	.198	Mass spectrometer
	I	4.5	3	-	.225	(1.5 kilobit engineering data included in Group I)
	DS	4.0	3	-	.198	Small drop sonde
		12.5			.621	
3	I	4.5			.225	
4	I	4.5	3	-	.225	
	II	65.0	3	-	3.255	First photo
	III	90.0	1	-	1.5	Sampled every third orbit, read out once/orbit
		159.5			4.980	
5	I	4.5	3	-	.225	
	III	90.0	1	-	1.5	Second repeat of previous data sample
		94.5			1.725	
6	I	4.5	3		.225	
	II	.5	3		.024	Reference sample (bio lab)
	III	90.0	1		1.500	Third repeat of previous data sample
		95.0			1.749	
7	I	4.5	3	-	.225	
	IIA	51.0	3	1	2.550	Second photo of series of 18
	IIB	.5	3	1	.024	First bio lab sample
	III	90.0	1	-	1.500	New Group III sample
		146.0			4.299	
8	I	4.5	3	-	.225	
	IIA	51.0	3	2	2.550	
	IIB	.5	3	2	.024	
	III	90.0	1	-	1.5	
		146.0			4.299	
9	I	4.5	3	-	.225	
	IIA	51.0	3	3	2.550	
	IIB	.5	3	3	.024	
	III	90.0	1	-	1.500	
		146.0			4.299	
10	I	4.5	3	-	.225	
	IIA	51.0	3	4	2.550	
	IIB	.5	3	2	.024	
	DS	90.0	1	-	1.500	Sonde data replaces Group III for 3 orbits
		146.0			4.299	
23	I	4.5	3	-	.225	
	IIA	51.0	3	19	2.550	Last photo of series
	IIB	.5	3	19	.024	
	III	90.0	1	-	1.500	
		146.0			4.299	
24	I	4.5	3	-	.225	
	IIB	.5	3	20	.024	
	III	90.0	1	-	1.500	
		95.0			1.749	
41	I	4.5	3		.225	
	IIB	.5	3	35	.024	Last bio lab sample of series
	III	90.0	1		1.500	
		95.0			1.749	
42	I	4.5	3		.225	This cycle continues until a Group II command is received, the cycle will then restart as shown at Orbit 4 above
	III	90.0	1		1.5	
		94.5			1.725	

TABLE 30. - POWER SUBSYSTEM COMPONENTS

Item	Rating	Weight	Volume	Status
Radioisotope thermoelectric generator	40 W	18 kg (40 lb)	14 000 cc (850 cu in.)	Circular planar design; silicon-germanium elements available; high-temperature fuel matrix requires development
Converter regulator	10 W	1 kg (2.2 lb)	1250 cc (76 cu in.)	Similar to existing solid-state designs
Battery charger	30 W	1.7 kg (3.7 lb)	2050 cc (125 cu in.)	Similar to existing solid-state designs
Nickel-cadmium battery	28 V, 6 AH (22 cells)	7.7 kg (17 lb)	4920 cc (300 cu in.)	Heat sterilized batteries available
Wiring and connectors		6.4 kg (14 lb)		

TABLE 31. - POWER SUBSYSTEM ENGINEERING MEASUREMENTS

	Range
1. RTG voltage	0 to 10 V
RTG current	0 to 10 A
RTG radiator temperature	400 to 700°F
2. Converter regulator output voltages	-10 to 15 V
3. Battery charges	
Output voltage	0 to 36 V
Output current	0 to 1 A
4. Battery	
Output voltage	
Fine	20 to 36 V
Coarse	0 to 36 V
Output current	0 to 10 A
Temperature	0 to 65°C

TABLE 32. - NONCYCLIC 5000-LB STATION, HYDROGEN GAS, 6-MB SUPERPRESSURE, 57 KM IN MEAN ATMOSPHERE

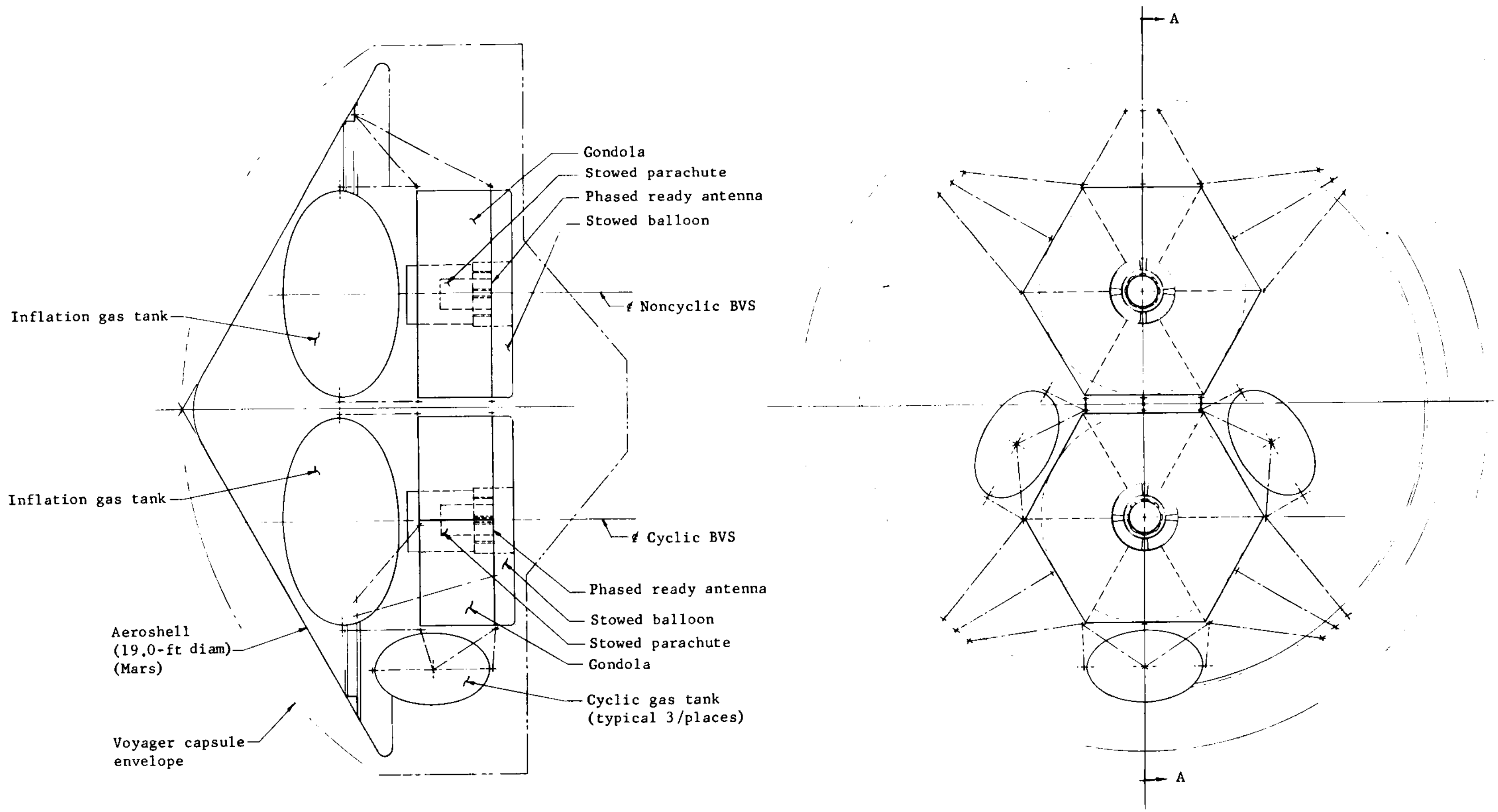
Parachute and deployment hardware weight		375 lb
Two-stage parachute system		
Balloon		
Volume	231 000 cu ft	
Diameter	76.2 ft	
Surface area	18 200 sq ft	
Balloon fabric	413 lb	
Risers and attachments	27 lb	
Balloon canister	100.0 lb	
Aeroshell attachment	100.0 lb	
	Weight	640 lb
Hydrogen inflation		
Gas for balloon inflation	170 lb	
Gas residual in tank	2 lb	
Gas tank	1890 lb	
Controls, valving, etc.	18 lb	
	Weight	2080 lb
Gondola		
	Weight	1905 lb
Weight lofted		
Balloon	440 lb	
Gas	170 lb	
Gondola	1905 lb	
	Total weight lofted	2515 lb
Buoyancy of station		2515 lb

TABLE 33. - 5000-LB NONCYCLIC STATION, CRYOGENIC HYDROGEN TRANSPORT, 6-MB SUPERPRESSURE, 57 KM IN MEAN ATMOSPHERE

Parachute and deployment hardware weight		375 lb
Two-stage parachute system		
Balloon		
Volume	340 000 cu ft	
Diameter	86.7 ft	
Surface area	23 570 sq ft	
Film thickness	3.77 mil	
Film	611 lb	
Risers and attachments	44 lb	
Balloon canister	100 lb	
Aeroshell attachments	100 lb	
	Weight	855 lb
Hydrogen inflation subsystem		
Gas for balloon	250 lb	
Residual	13 lb	
Launch cryogen	600 lb	
Tankage, HX, controls	340 lb	
	Weight	940 lb
Gondola		
	Weight	2830 lb
Weight lofted		
Balloon	645 lb	
Gas	250 lb	
Gondola	2830 lb	
	Total weight	3735 lb
Buoyancy of station		3735 lb

TABLE 34. - CYCLIC 5000-LB STATION, GAS DUMP AND MAKEUP, HYDRAZINE CYCLE SUBSYSTEM (3 CYCLES TO 10 KM, 6-MB SUPERPRESSURE, HYDROGEN-INFLATED BALLOON, 57 KM IN MEAN ATMOSPHERE)

Parachute and deployment hardware weight		375 lb
Two stage parachute system		
Balloon		
Volume	340 000 cu ft	
Diameter	86.7 ft	
Surface area	23 570 sq ft	
Balloon (PBI film)	611 lb	
Risers and attachments	44 lb	
Balloon canister	100 lb	
Aeroshell attachment	100 lb	
	Weight	855 lb
Hydrogen inflation		
Gas for balloon inflation	250 lb	
Residual in tank	13 lb	
Cryogen at launch	600 lb	
Tank, HX, controls	340 lb	
	Weight	940 lb
Hydrazine cycle subsystem		
First cycle		
Gas	236 lb	
Residual gas	12 lb	
Tankage	25 lb	
Controls, valving, etc.	10 lb	
Second cycle		
Gas	227 lb	
Residual gas	12 lb	
Tankage	25 lb	
Controls, valving, etc.	10 lb	
Third cycle		
Gas	214 lb	
Residual gas	11 lb	
Tankage	25 lb	
Controls, valving, etc.	10 lb	
	Weight	817 lb
Gondola		
	Weight	2013 lb
Weight lofted (initial)		
Balloon	645 lb	
Gas	250 lb	
Cycle subsystem	817 lb	
Gondola	2013 lb	
	Total weight lofted	3725 lb
Buoyancy (initial)		3735 lb



A-A

Figure 1. - Two 2000-lb Stations in Voyager Capsule

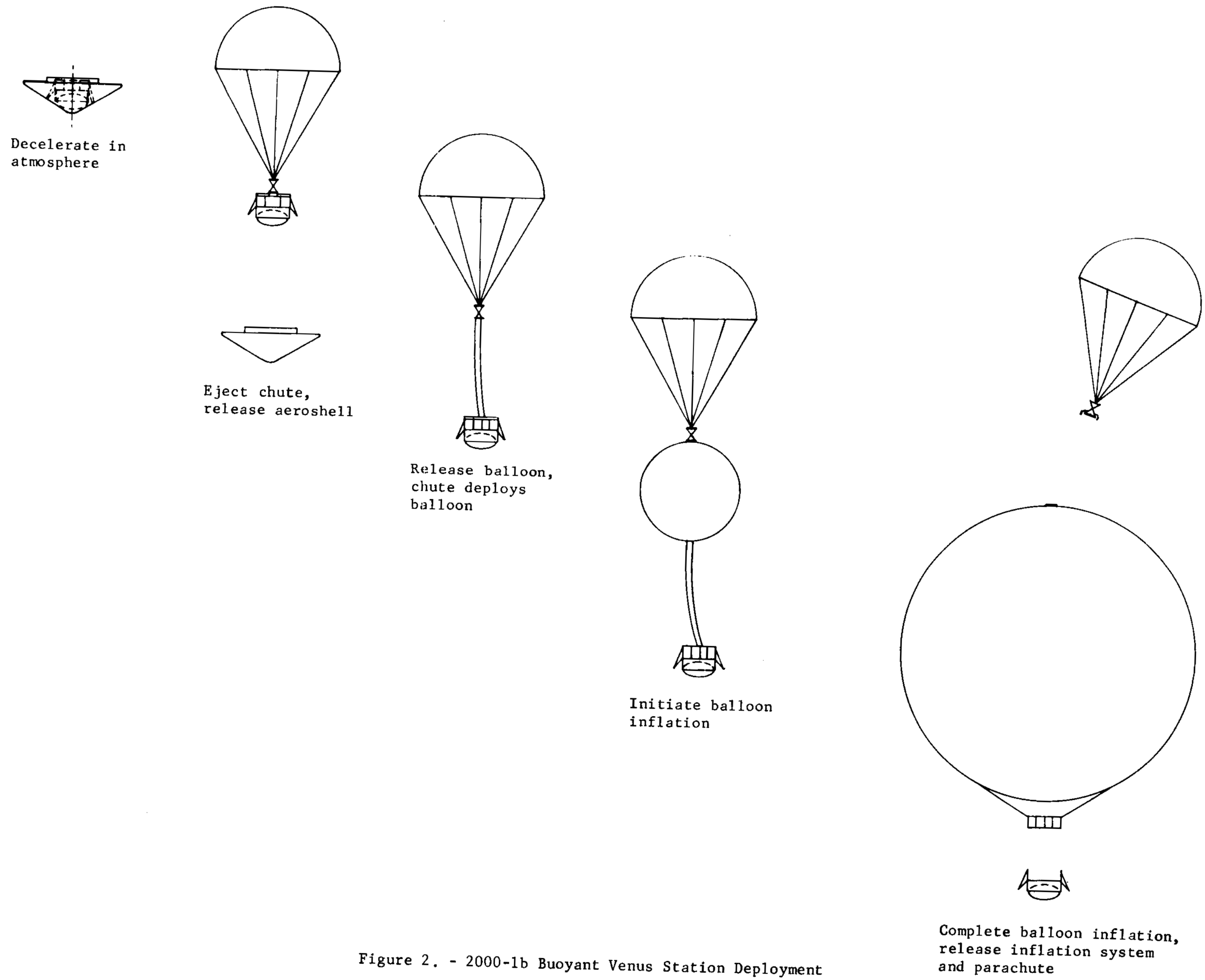
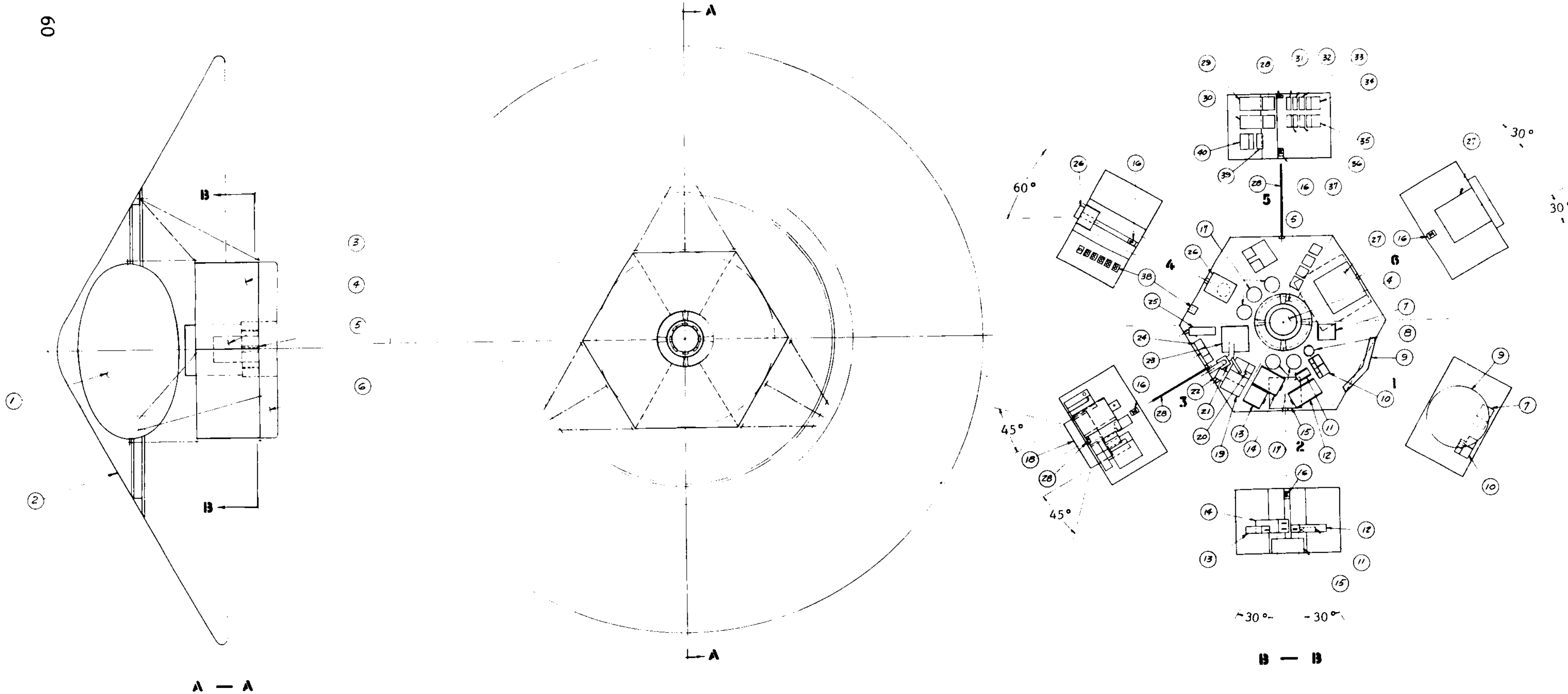


Figure 2. - 2000-lb Buoyant Venus Station Deployment



Legend:

1. Inflation tank
2. Voyager Mars aeroshell (19-ft diam)
3. Gondola
4. Stowed parachute
5. Phased array antenna
6. Stowed balloon
7. Battery
8. Balloon inflation hose
9. RTG power supply
10. Junction box, switches, and relays
11. Diplexer
12. Transmitter
13. Command receiver
14. Command decoder
15. Radar altimeter
16. Pressure sensor (total 10 req)
17. Drop sonde tubes (total 5 req)
18. Drop sonde antenna
19. Gas chromatograph
20. Vidicon microscope
21. Dust-sampler (for vidicon microscope)
22. Sampler (atmosphere and clouds)
23. Micro-biology laboratory)
24. Mass spectrometer
25. Acoustic densitometer
26. IR scanner/spectrometer
27. Microwave spectrometer/scanner
28. Temperature sensors-boom mounted (2 req)
29. Group III/DS memory
30. Group IIA memory
31. Data package 1
32. Data package 2
33. Data package 3
34. Data selector
35. Programer/sequencer
36. Group I memory
37. Group II memory
38. Aerosol detectors
39. Drop sonde receiver
40. Drop sonde bit synchronizer and signal conditioner

Figure 3. - 2000-lb Buoyant Venus Station

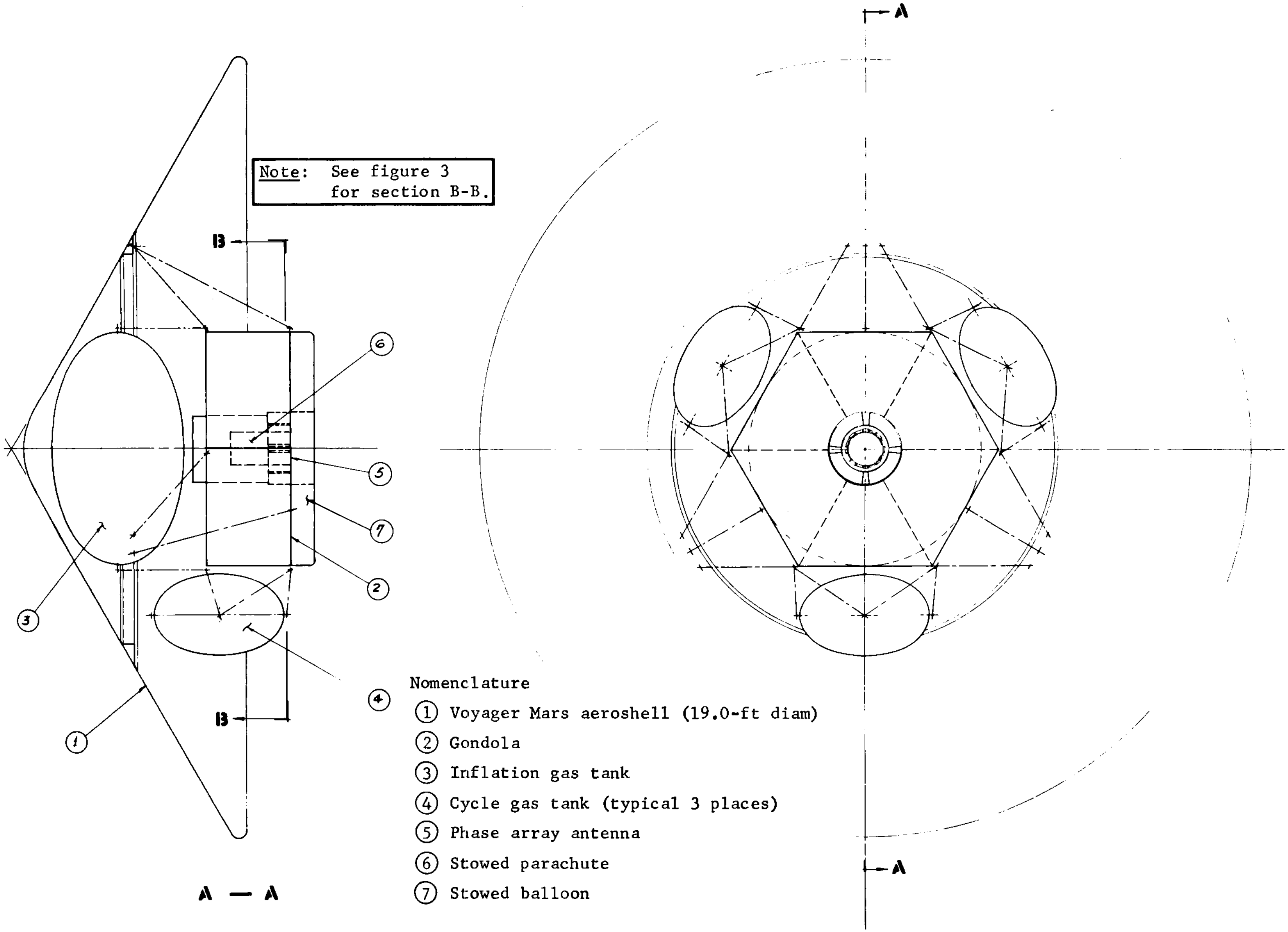


Figure 4. - Cyclic 2000-1b Buoyant Venus Station

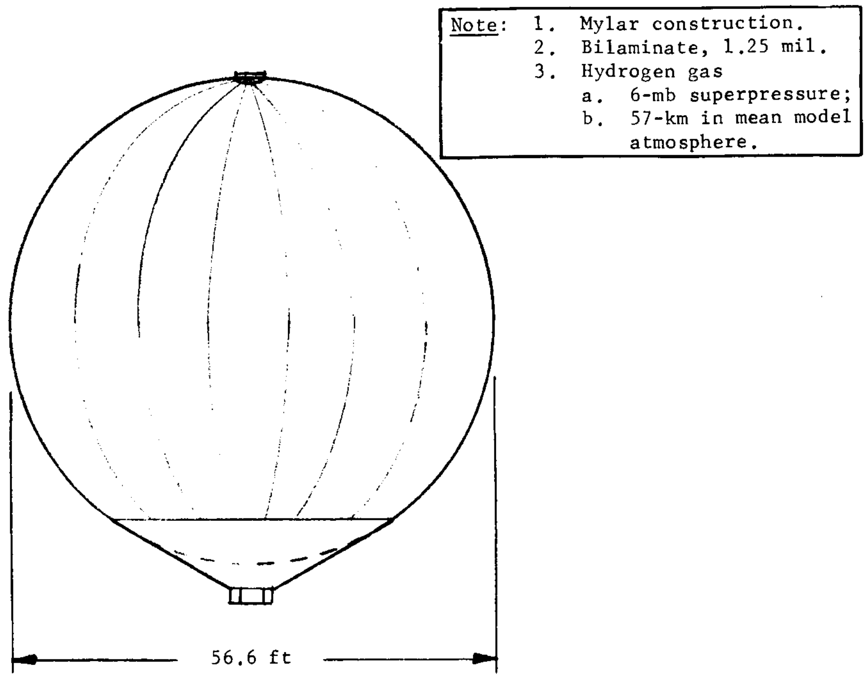


Figure 5. - Noncyclic 2000-1b Station

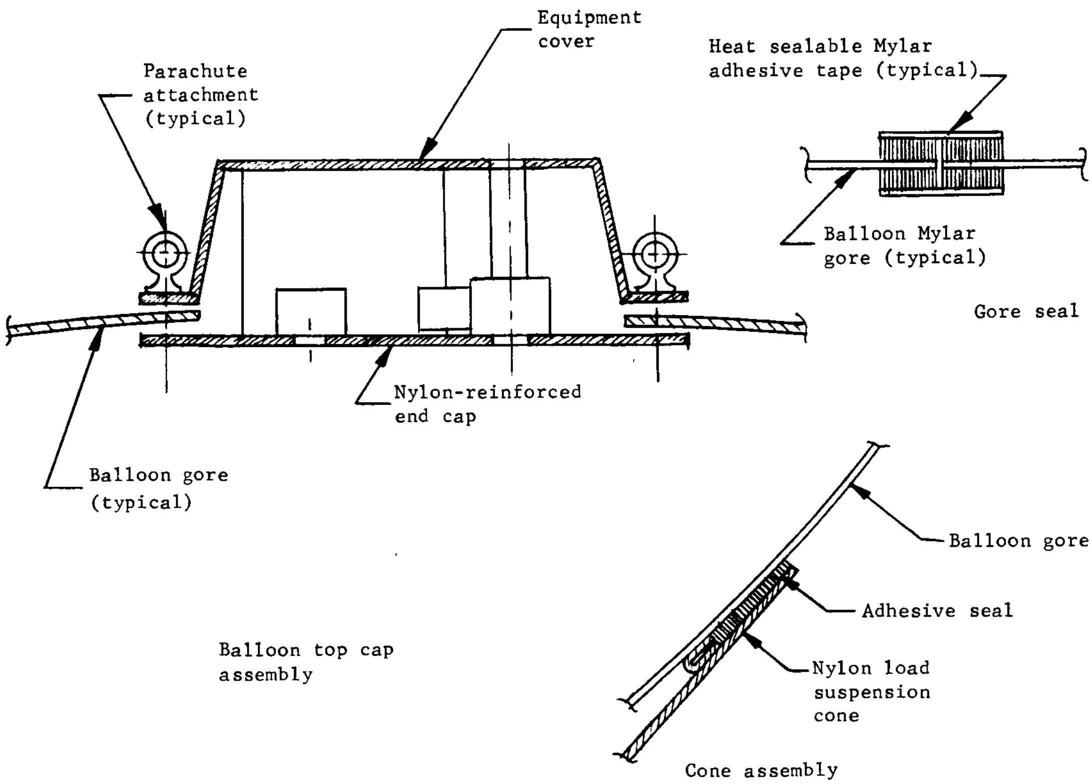


Figure 6. - Noncyclic Balloon Assembly Details

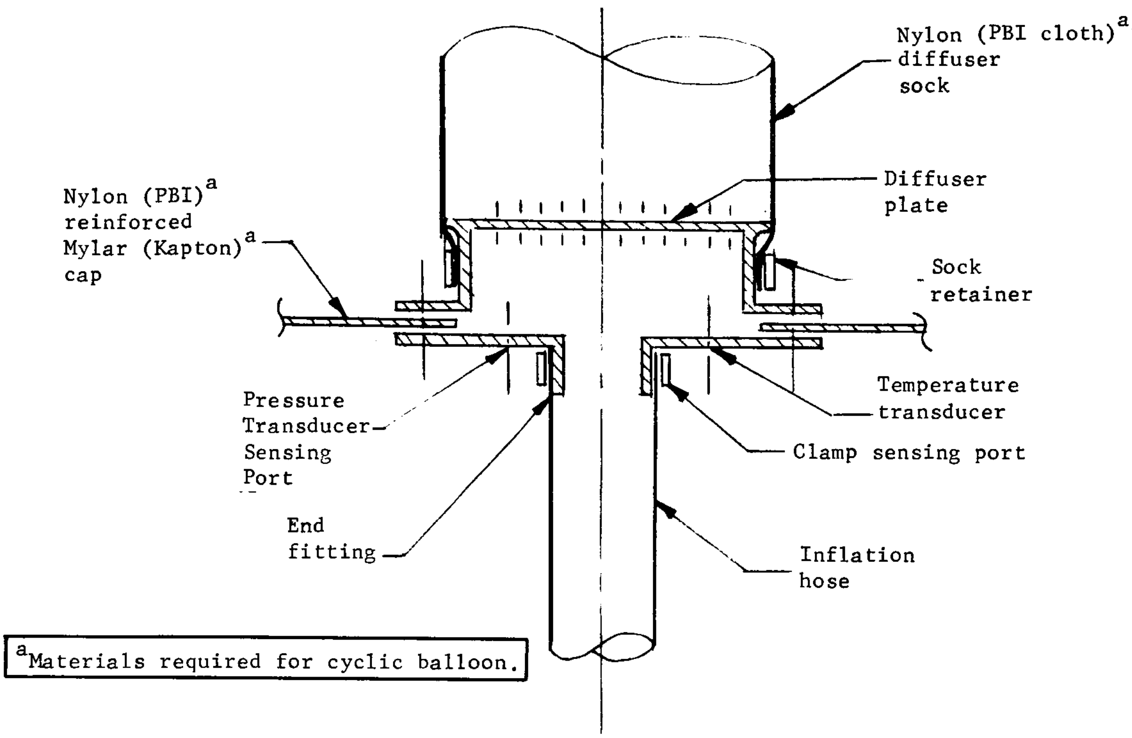


Figure 7. - Balloon Inflation Fitting Details

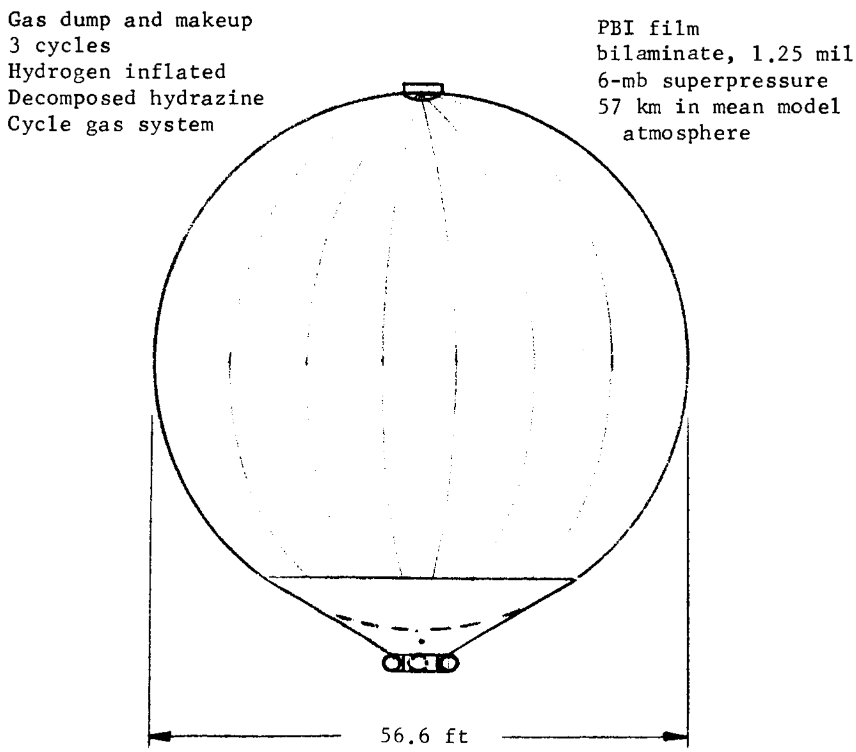


Figure 8. - 2000-lb Cyclic Station

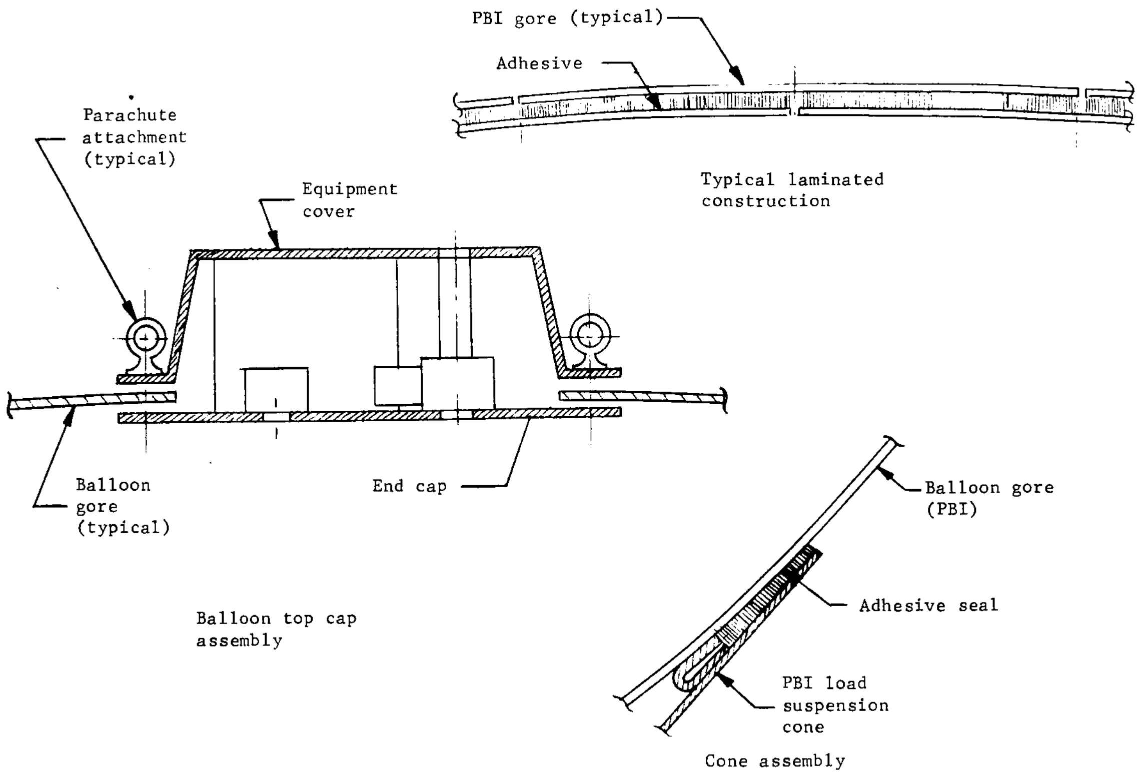


Figure 9. - Cyclic Balloon Assembly Details

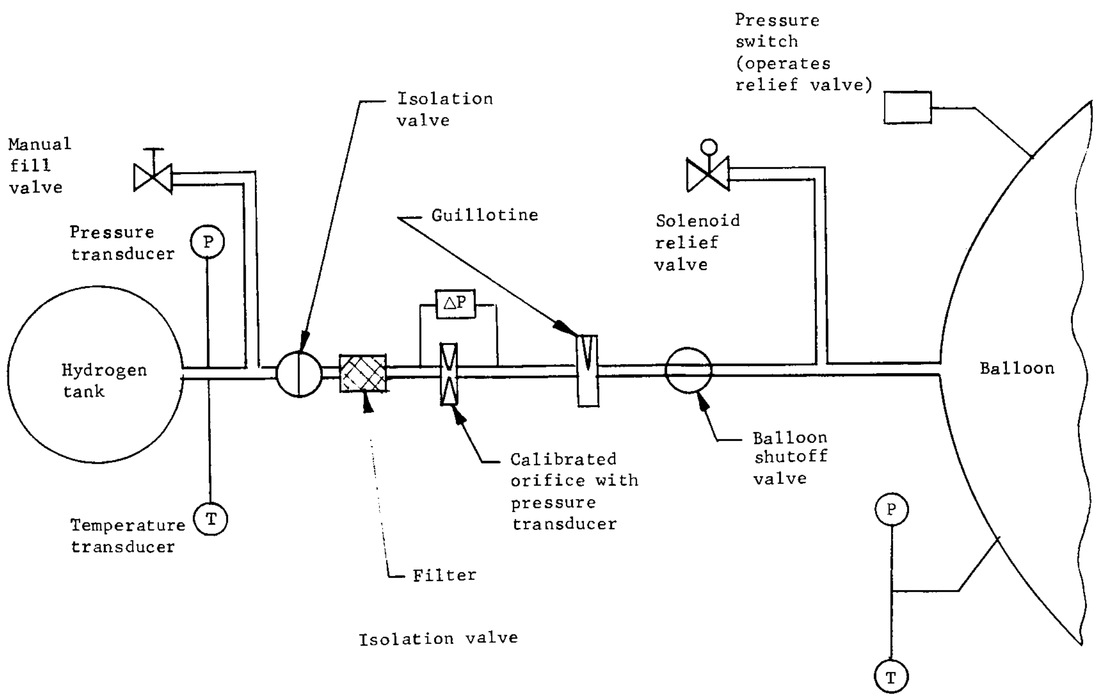


Figure 10. - Inflation Gas System

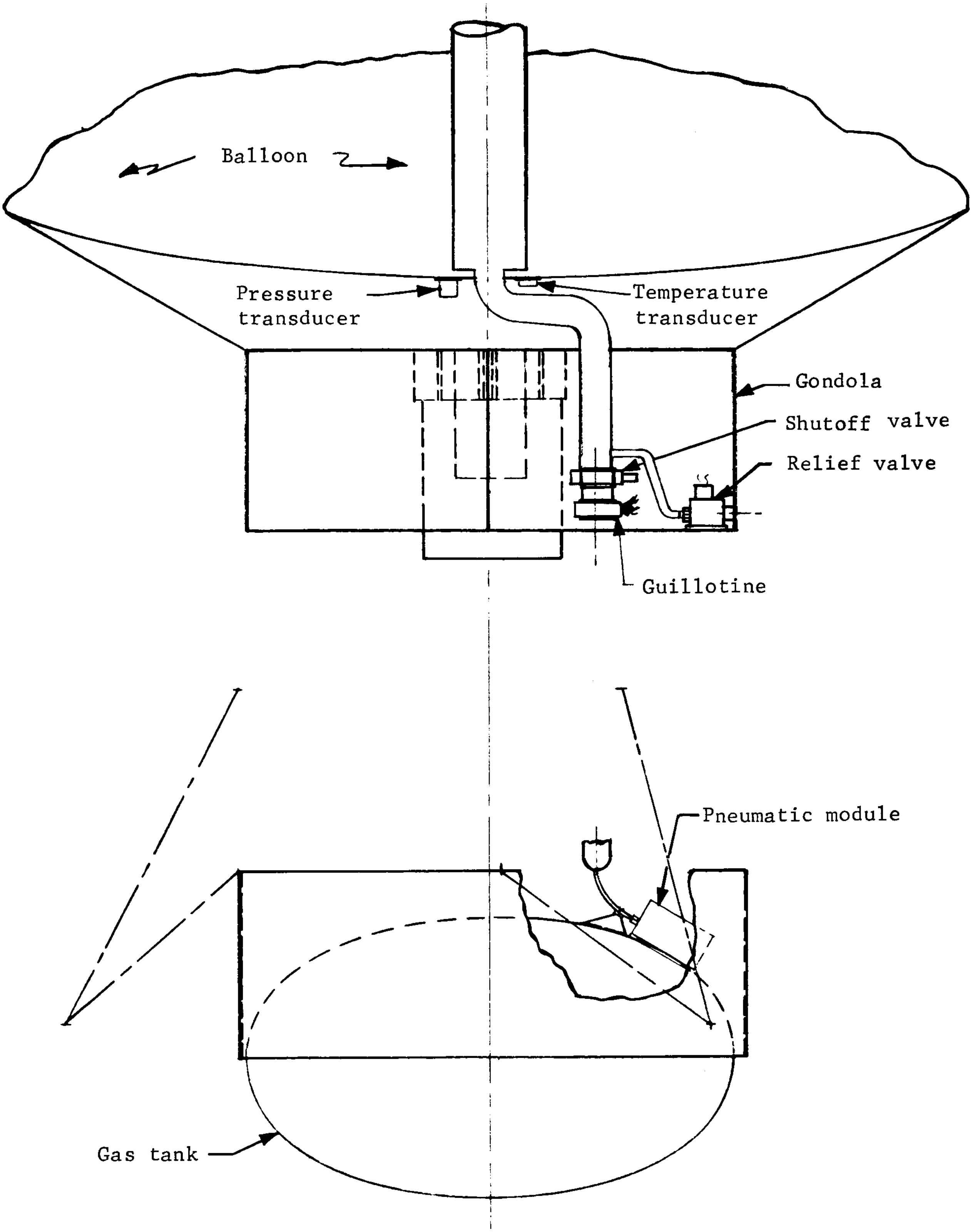


Figure 11. - Inflation System Separation

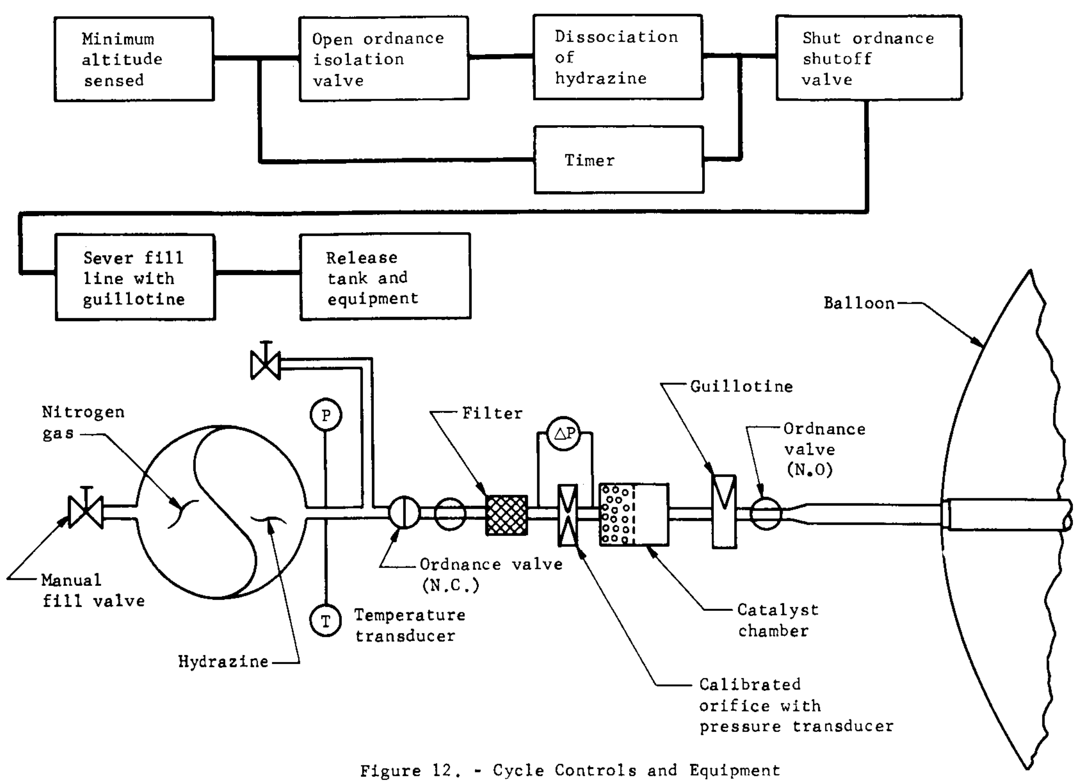


Figure 12. - Cycle Controls and Equipment

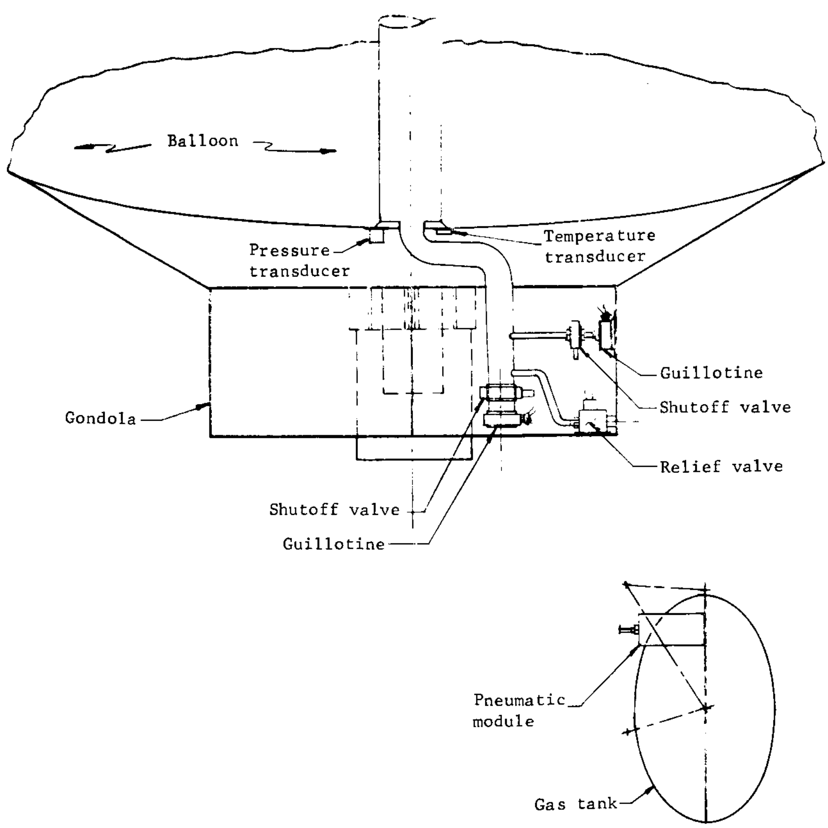


Figure 13. - Cycle Gas System Separation

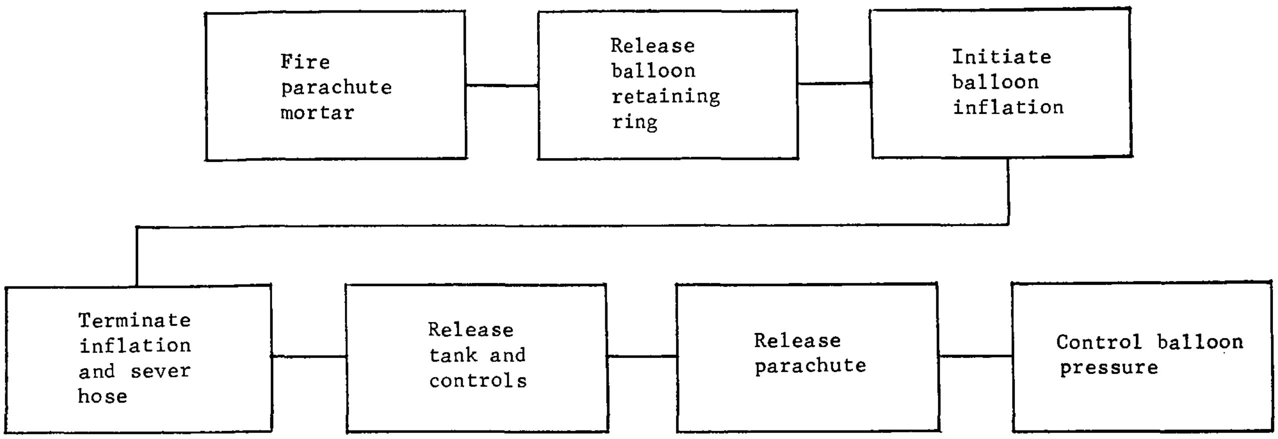


Figure 14. - Station Deployment Sequence

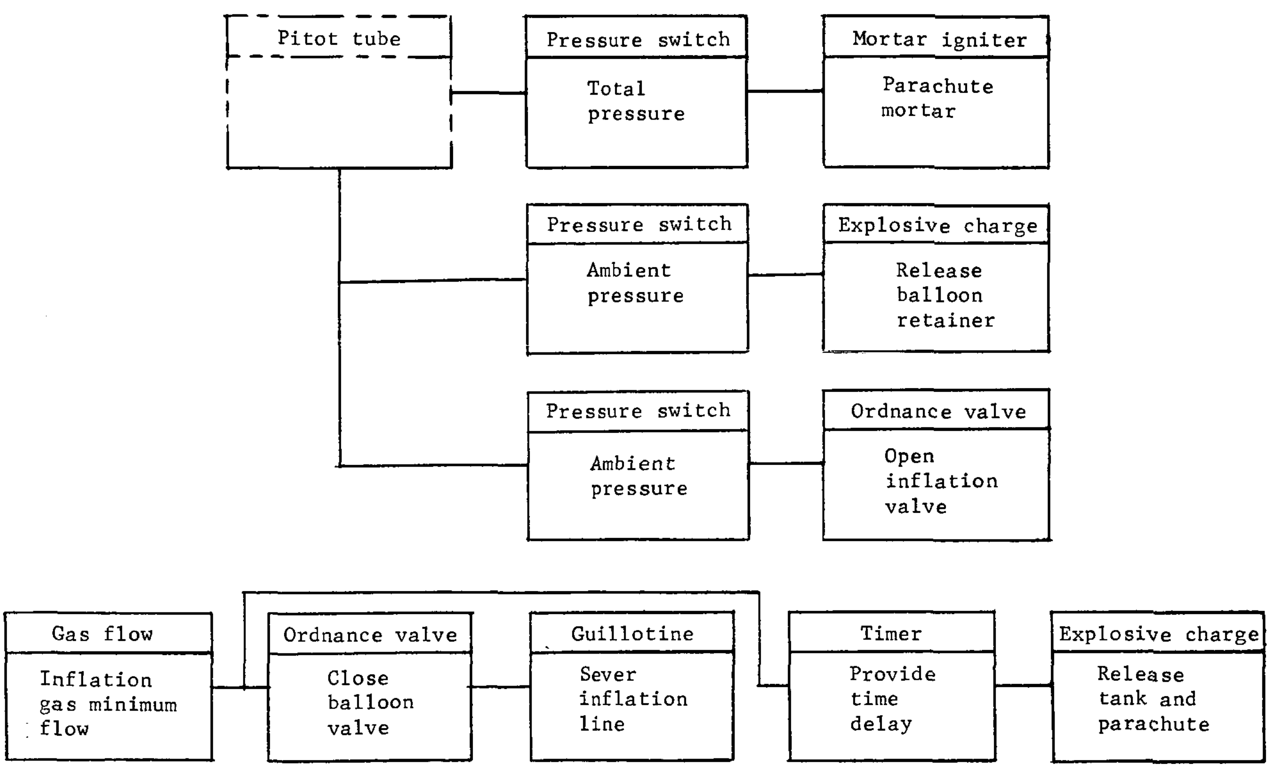


Figure 15. - Station Deployment Equipment

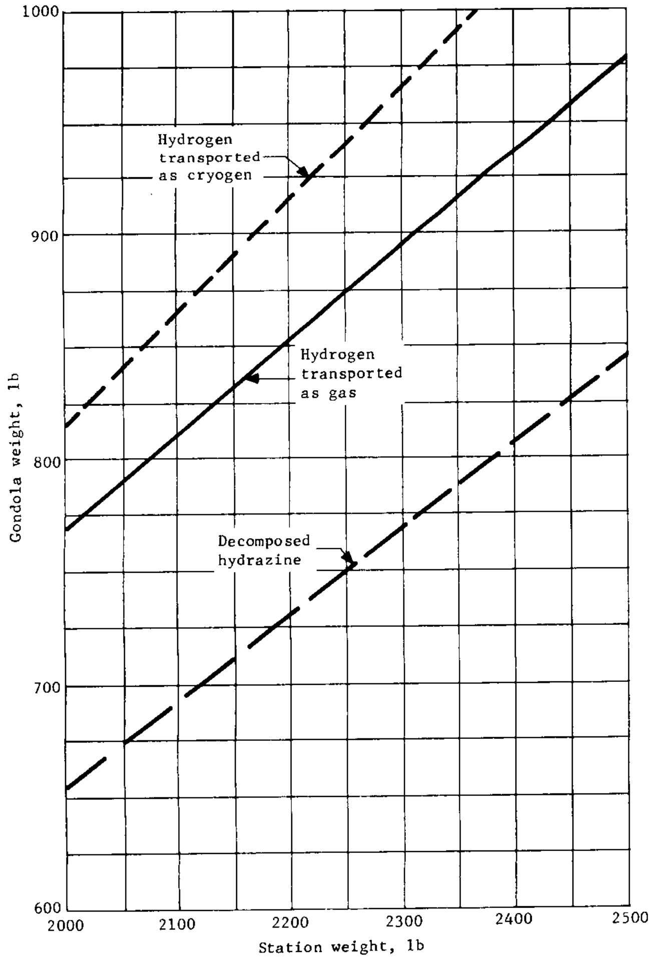


Figure 16. - Payload Capability for Two Gases at 57 km in Mean Atmosphere

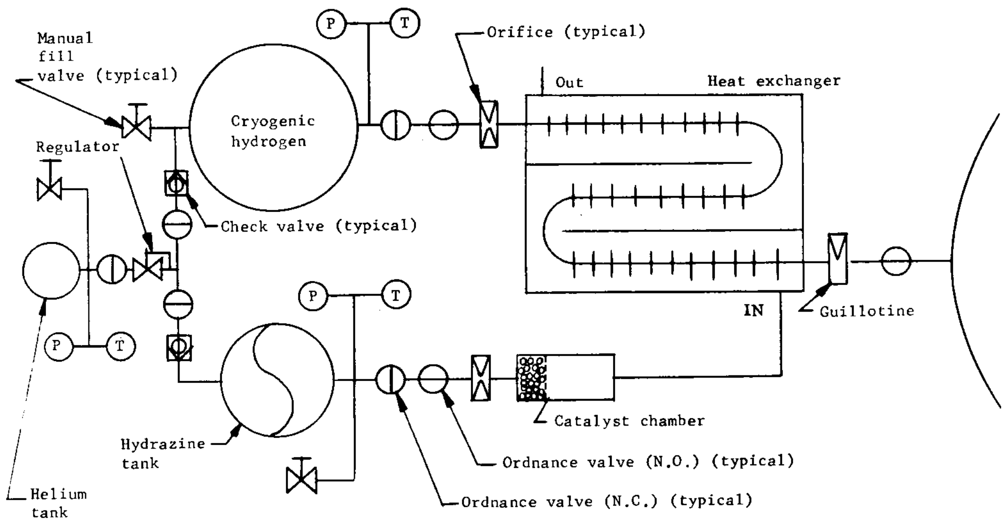


Figure 17. - Cryogenic Gas Inflation System

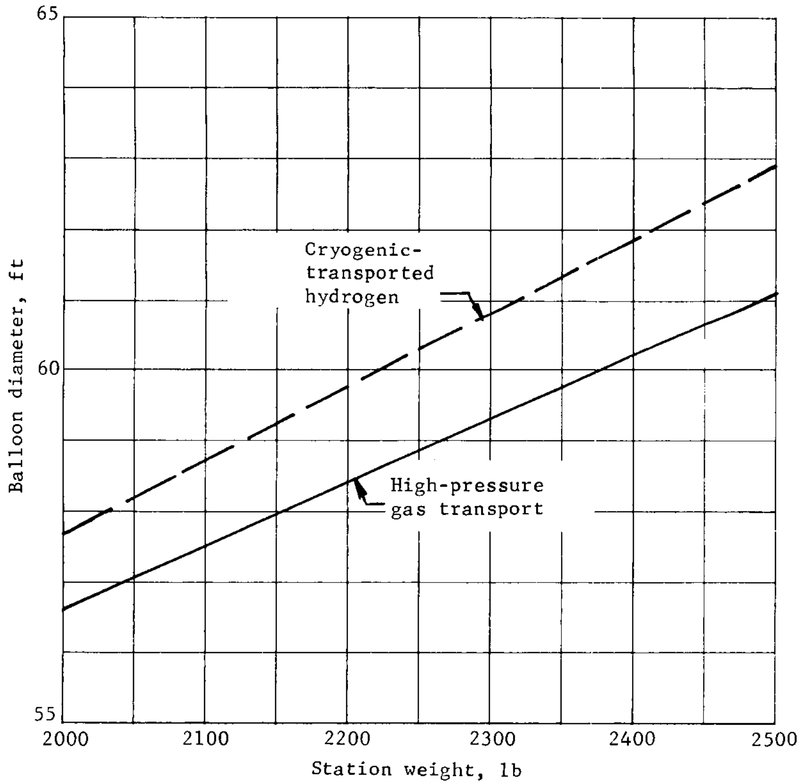


Figure 18. - Hydrogen Gas-Inflated Balloon Sizes for 57 km Altitude in Mean Atmosphere

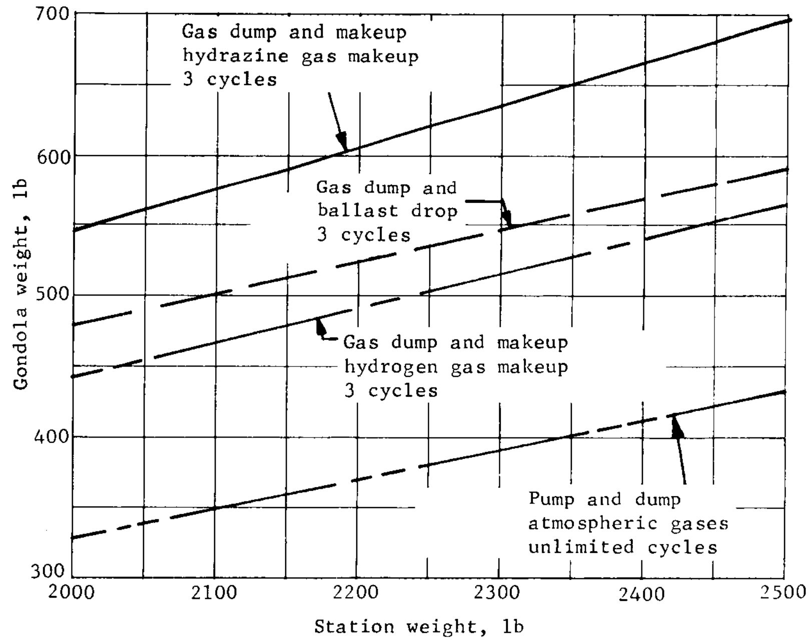


Figure 19. - Payload Weight for Three Altitude Cycling Methods, Hydrogen-Inflated Balloon Cycled between 57 and 10 km in the Mean Atmopshere

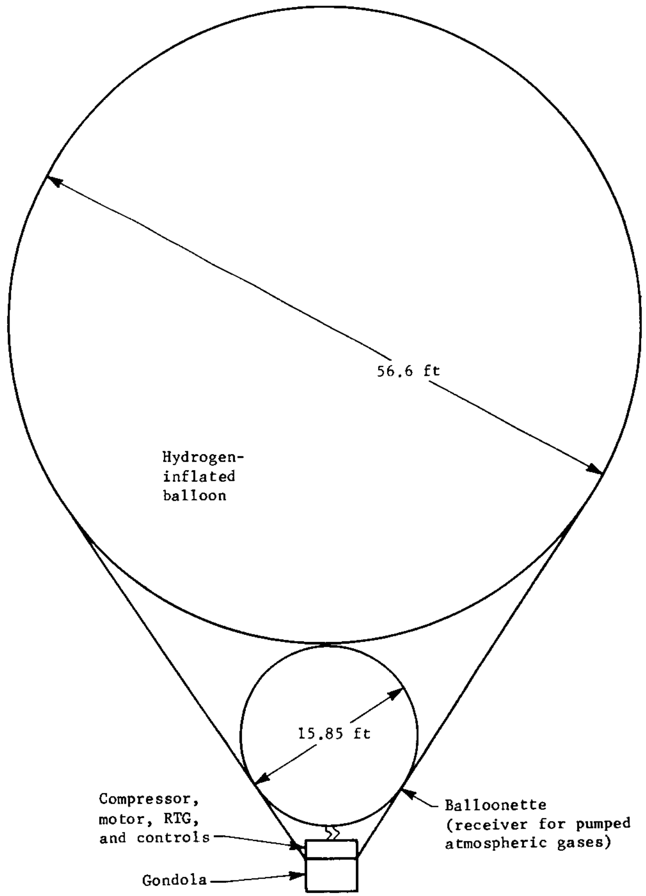


Figure 20. - 2000-lb Cyclic Station Pump and Dump Atmospheric Gases

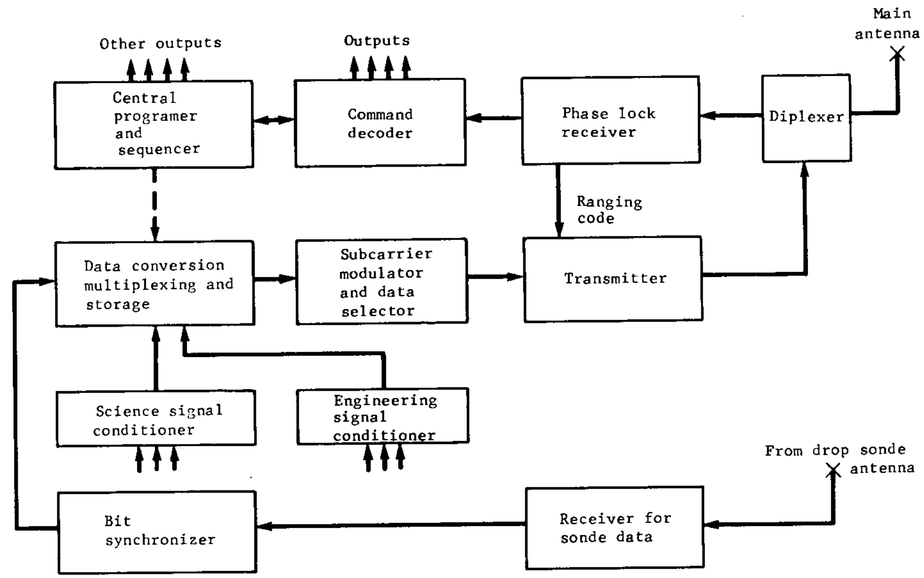


Figure 21. - Telecommunications Simplified Block Diagram

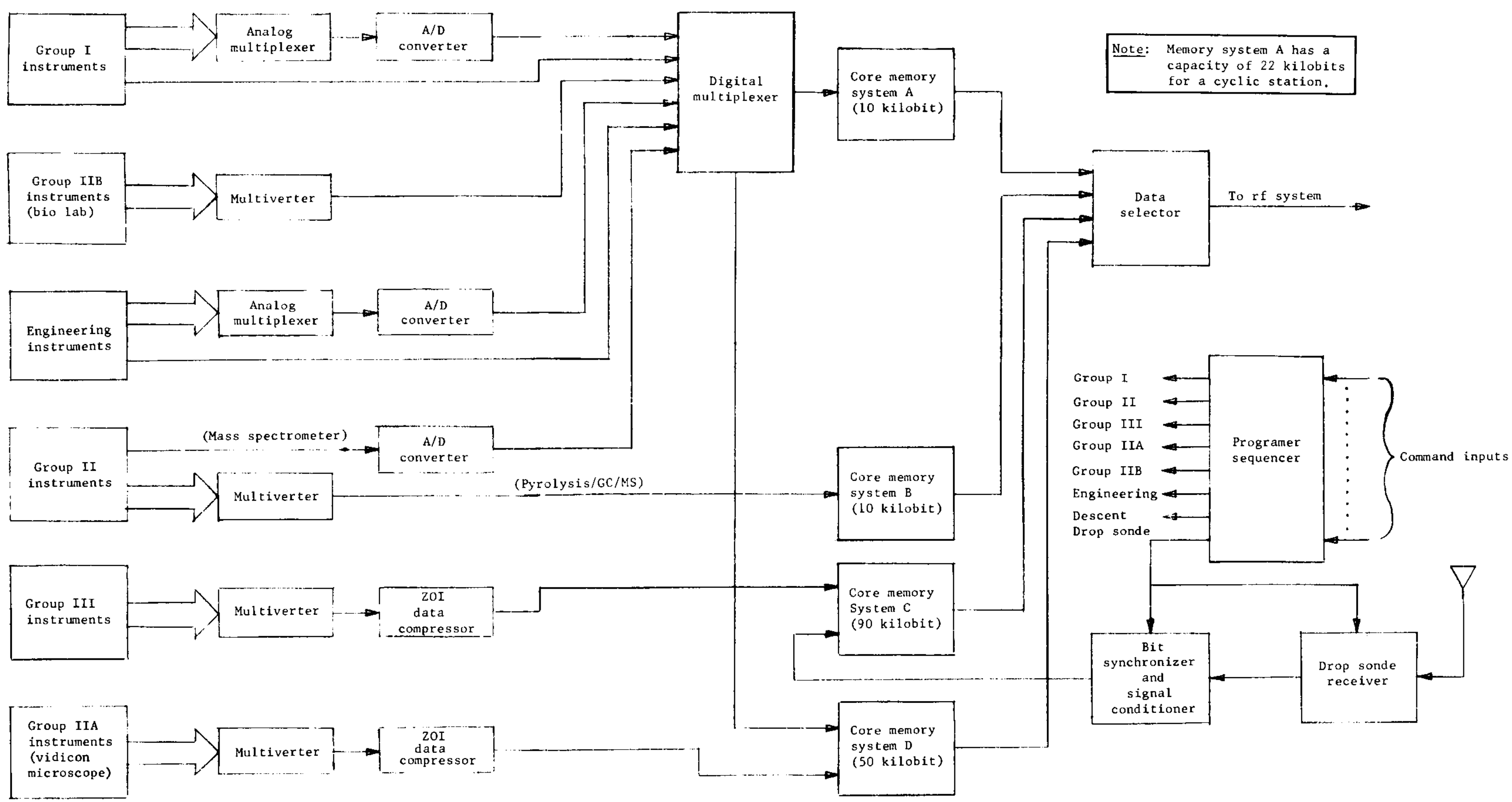


Figure 22. - Data Management Block Diagram, 2000-lb Station

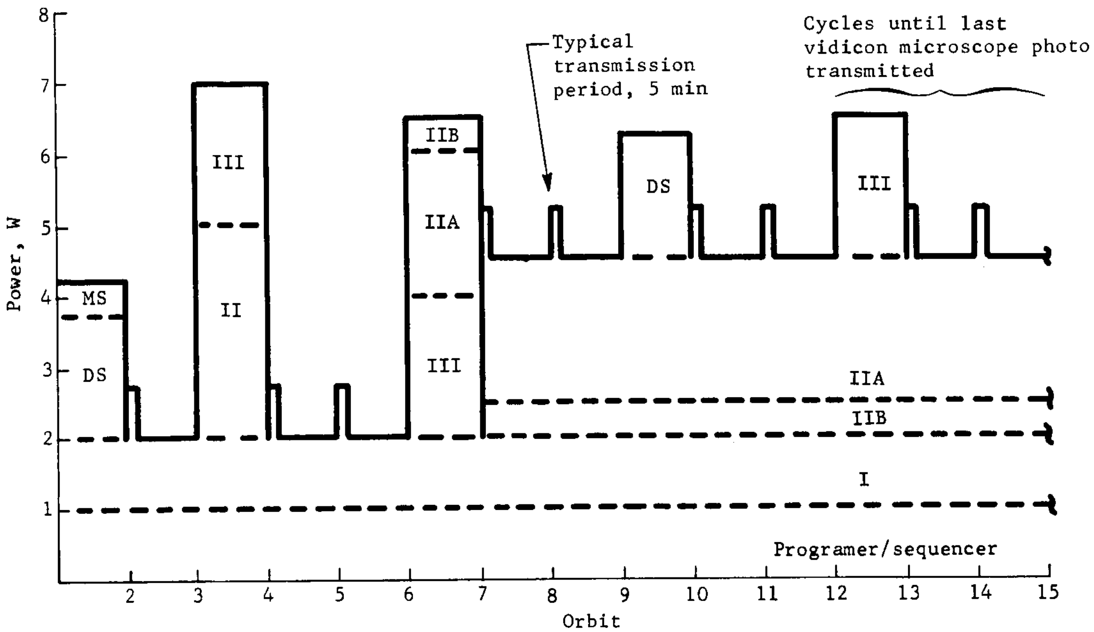


Figure 23. - Data Management Power Profile, Part I

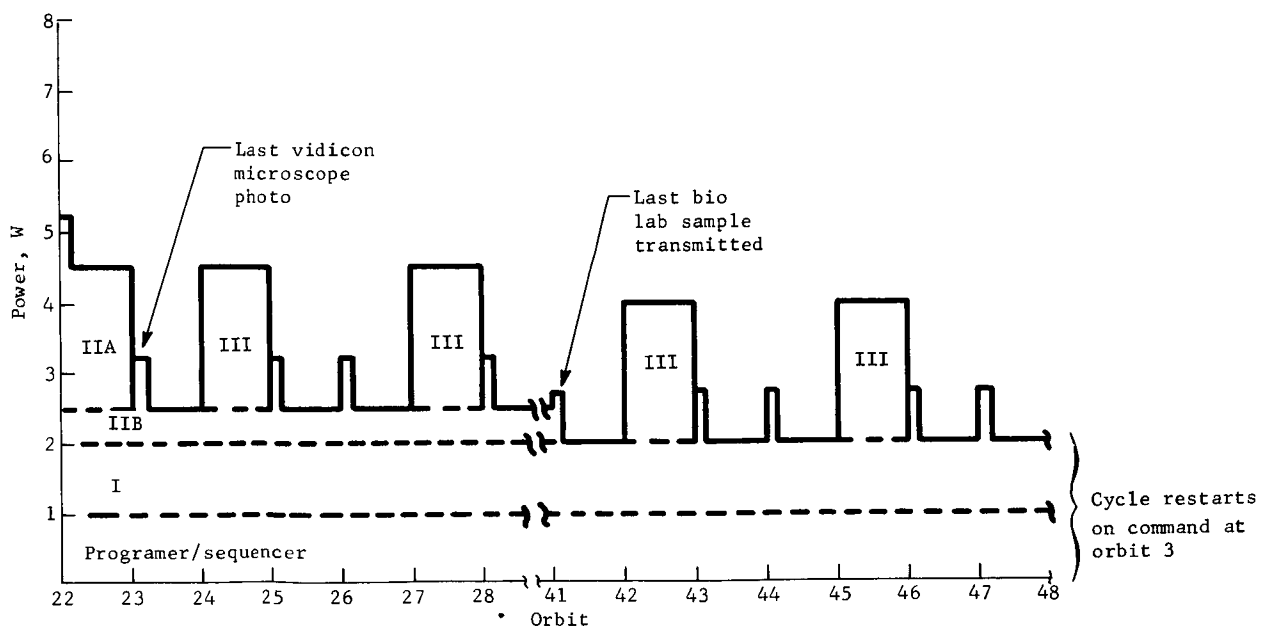


Figure 24. - Data Management Power Profile, Part II

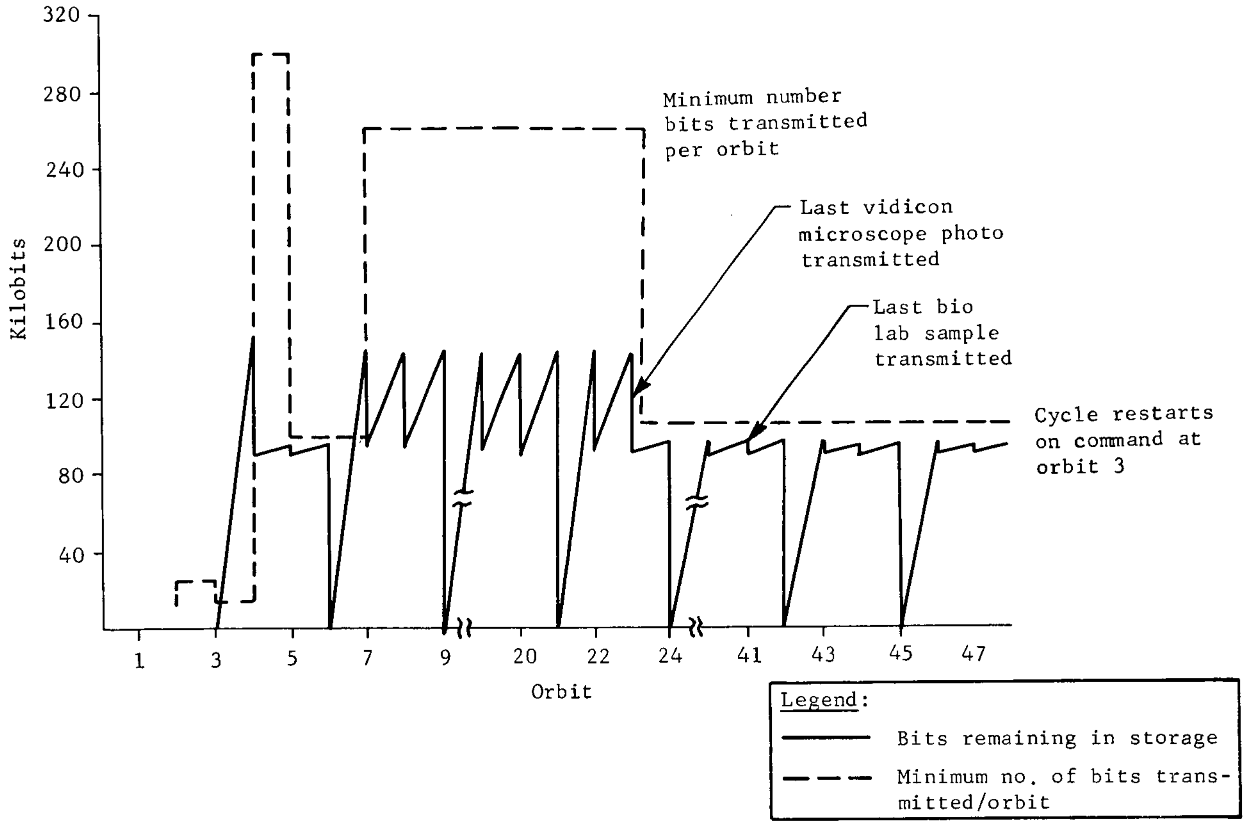
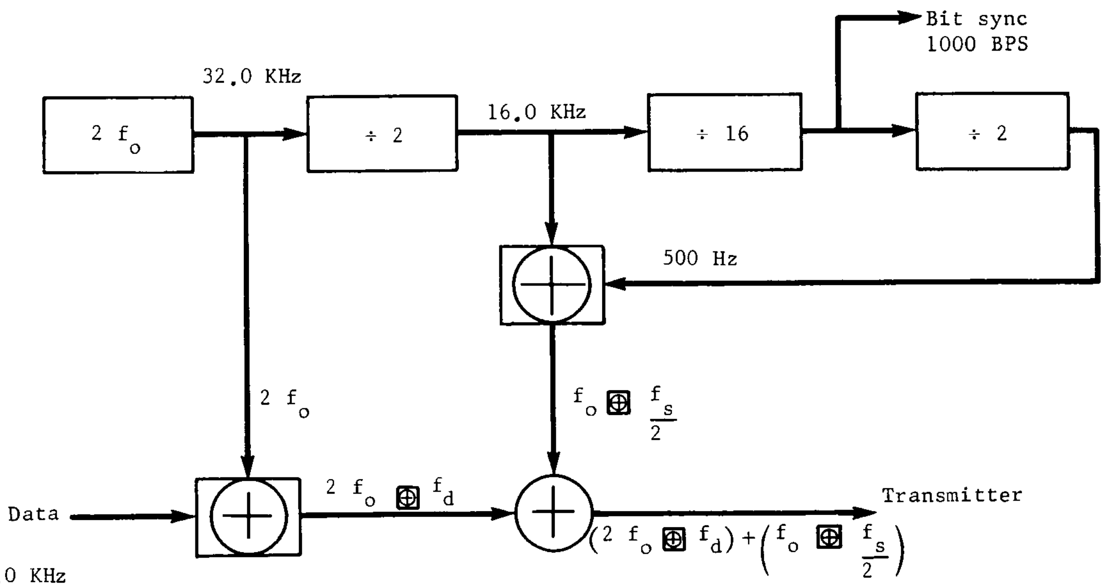


Figure 25. - Total Data Storage and Transmission Requirements per Orbit



$2f_o$ = 32.0 KHz

f_s = 1000 Hz

f_d = 1000 BPS (data)

Figure 26. - Two-Channel Modulator

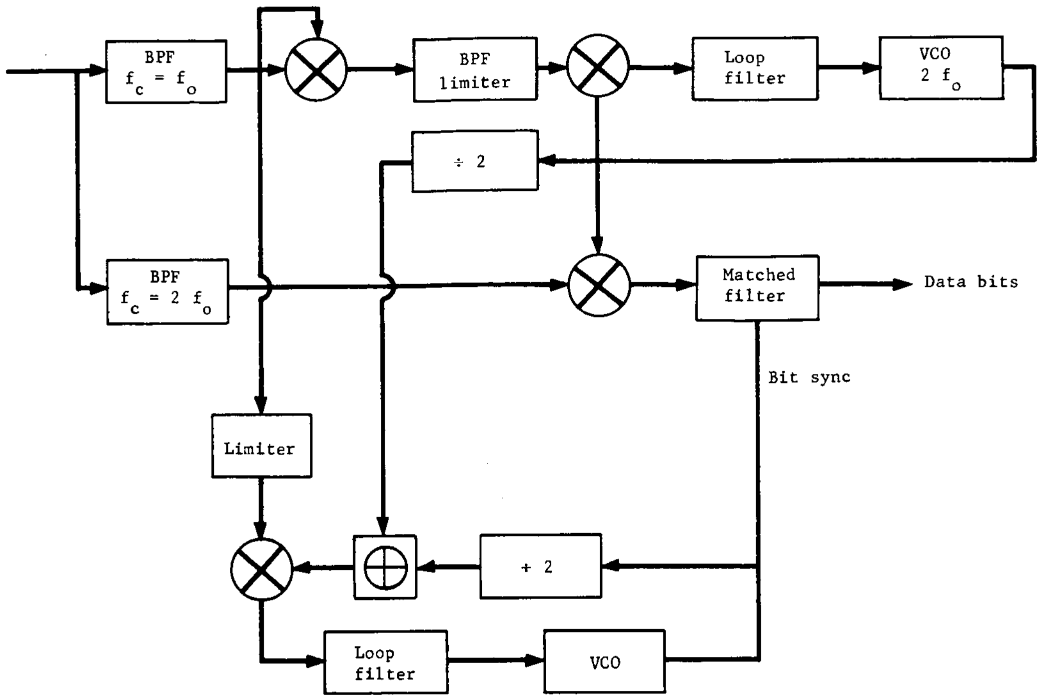


Figure 27. - Two-Channel Demodulator

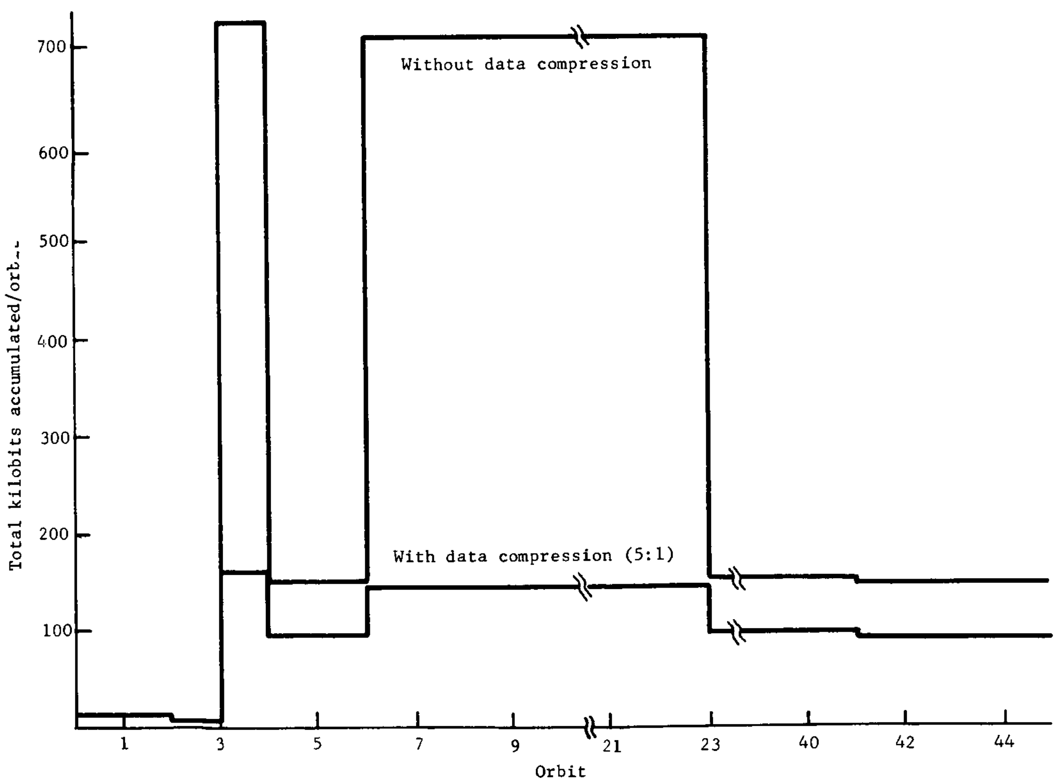


Figure 28. - Data Accumulation per Orbit Compression Tradeoff

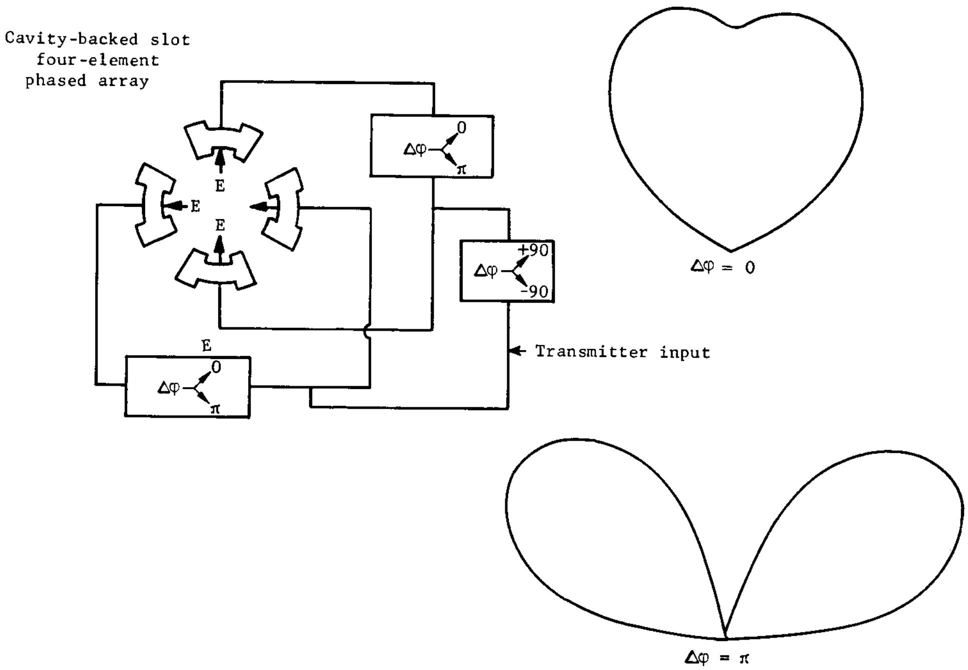


Figure 29. - Main Antenna Array

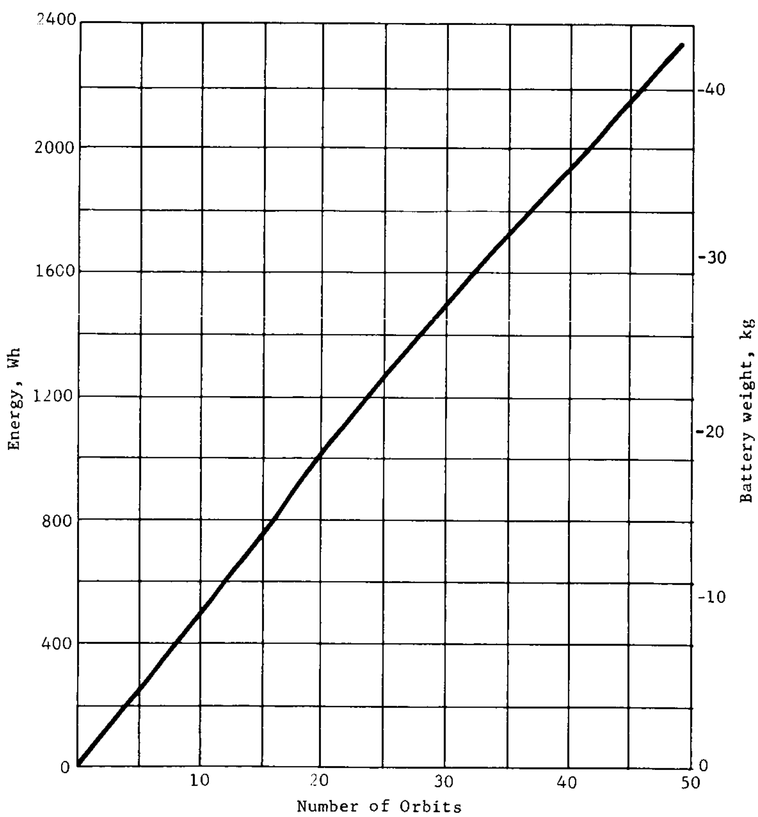


Figure 30. - Energy Requirements and Corresponding Battery Weight vs Number of Orbits

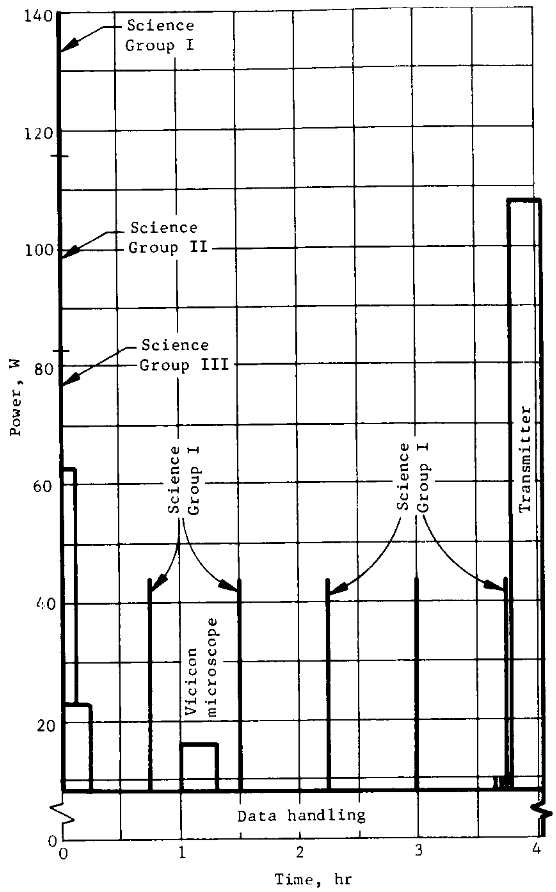


Figure 31. - Power Profile for Orbit 3

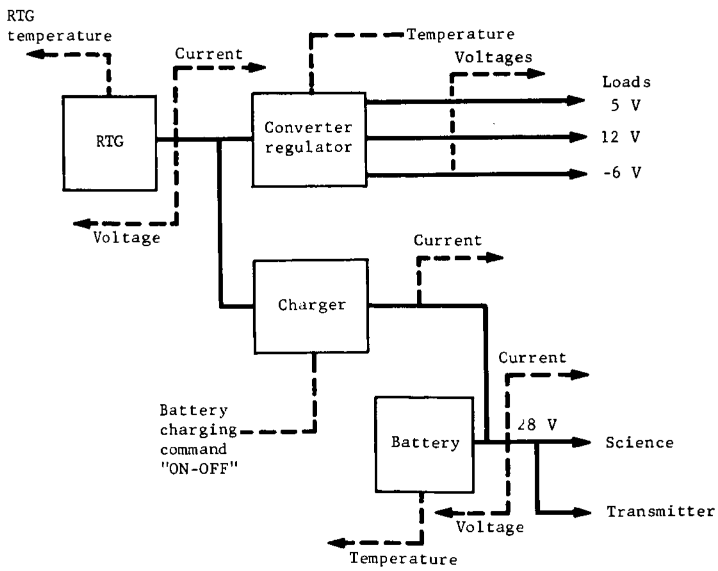


Figure 32. - Power System Block Diagram

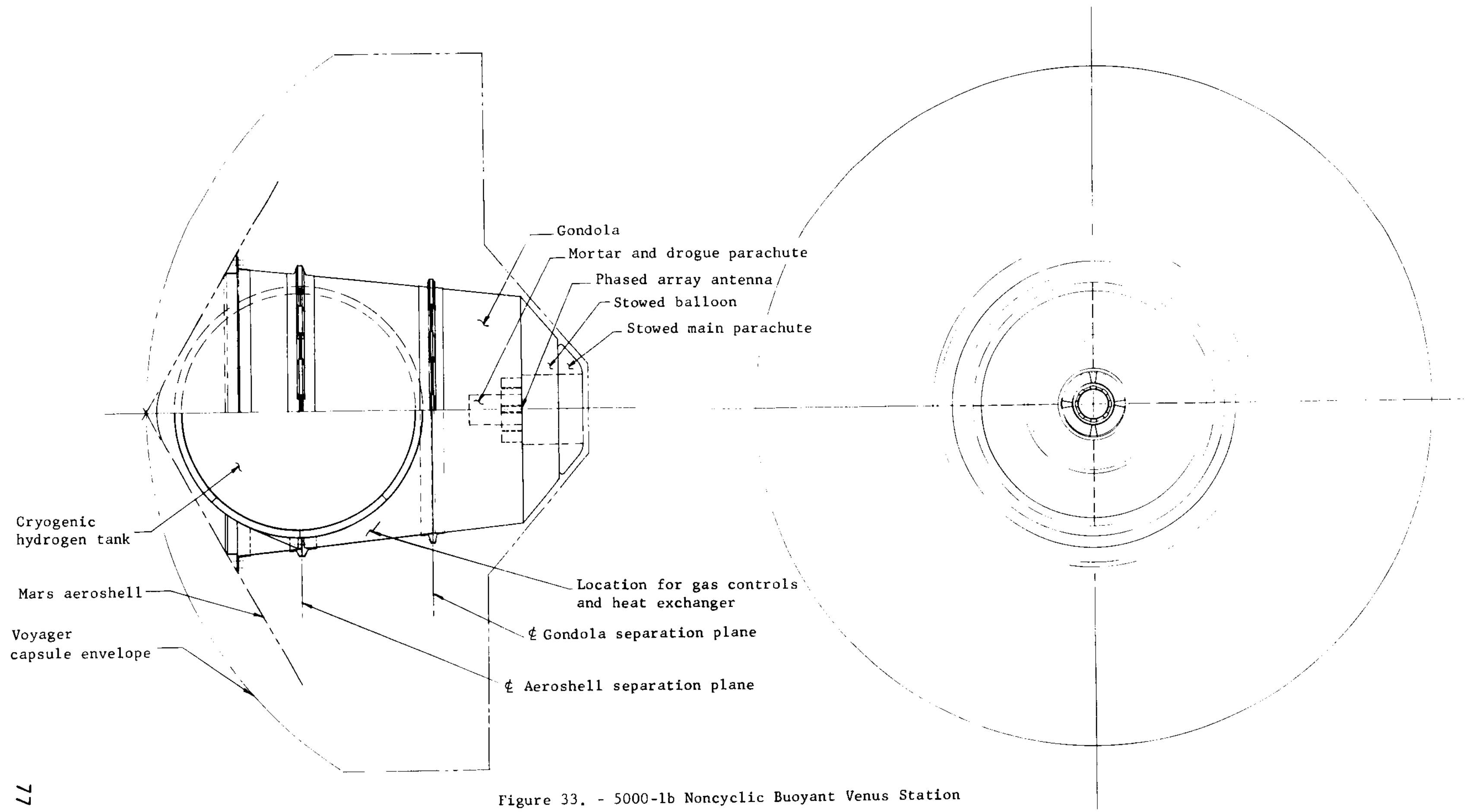


Figure 33. - 5000-lb Noncyclic Buoyant Venus Station

REFERENCE

1. Golomb, S. et al.: Digital Communications with Space Applications. Prentice-Hall, Inc., 1964.